Report to the Space Science Board

on the

SPACE SCIENCE

AND

APPLICATIONS PROGRAMS

November 1964

NASA Headquarters Washington 25, D. C.

SPACE SCIENCE & APPLICATIONS PROGRAMS

Presented to the Space Science Board

by

Dr. H. E. Newell

Associate Administrator for
Space Science & Applications

NASA Headquarters

November 1964

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PAST ACCOMPLISHMENTS

The following is a list of the successful major satellite and space probe firings that have been carried out in connection with the NASA program since the creation of NASA in 1958:

1958

PIONEER I	Magnetic field, radiation belts
PIONEER II	Magnetic field, radiation belts, cosmic rays
PIONEER III	Radiation belts, cosmic rays

1959

VANGUARD II	Cloud cover
PIONEER IV	Radiation belts, cosmic rays
EXPLORER VI	Magnetic field, radiation belts
VANGUARD III	Magnetic field
EXPLORER VII	Radiation belts, cosmic rays, thermal radiation, micrometeors

1960

PIONEER V	Magnetic field, cosmic rays
TIROS I	Cloud cover
ECHO I	Air density, passive communications
EXPLORER VIII	Ionosphere, micrometeors
TIROS II	Cloud cover, thermal radiation

1961

EXPLORER IX	Air density
EXPLORER X	Magnetic field, plasma
EXPLORER XI	Gamma radiation

(1961 - Continued)

TIROS III	Cloud cover, thermal radiation
EXPLORER XII	Magnetic field, radiation belts, cosmic rays
EXPLORER XIII	Micrometeoroids
	1962
TIROS IV	Cloud cover, thermal radiation
OSO I	Electromagnetic radiation from sun
ARIEL I	Ionosphere, radiation
TIROS V	Cloud cover
TELSTAR I	Active communications
MARINER II	Energetic particles and magnetic fields, cosmic dust, Venus IR and microwave radiation
TIROS VI	Cloud cover
ALOUETTE	Ionosphere topside sounding, radio noise, cosmic rays
EXPLORER XIV	Energetic particles, magnetic field, cosmic rays
EXPLORER XV	Radiation Belts
ANNA 1-B	Geodesy
RELAY I	Active communications, radiation
EXPLORER XVI	Micrometeoroids, radiation
	1963
EXPLORER XVII	Atmosphere structure
TELSTAR II	Active communications

(1963 - Continued)

TIROS VII	Cloud cover
SYNCOM II	Active communications, synchronous orbit
EXPLORER XVIII	Interplanetary Explorer, particles and fields, solar wind shock wave
CENTAUR 2	First successful development flight, instrumented with sensors and telemetry
EXPLORER XIX	Air density
TIROS VIII	Cloud cover, Automatic Picture Transmission (APT) system for real-time readout of local cloud pictures

<u>1964</u>

RELAY II	Active communications, low altitude orbit
ECHO II	Passive communications
ARIEL II	International (US-UK) satellite, ozone distribution sampling, galactic radio noise
RANGER VII	Lunar photography
SYNCOM III	Active communications, synchronous orbit
EXPLORER XX	Ionospheric measurement by topside sounding
NIMBUS I	Global cloud cover, APT for local read-out, HRIR for nighttime cloud pictures
EXPLORER XXII	Ionospheric measurement, laser tracking

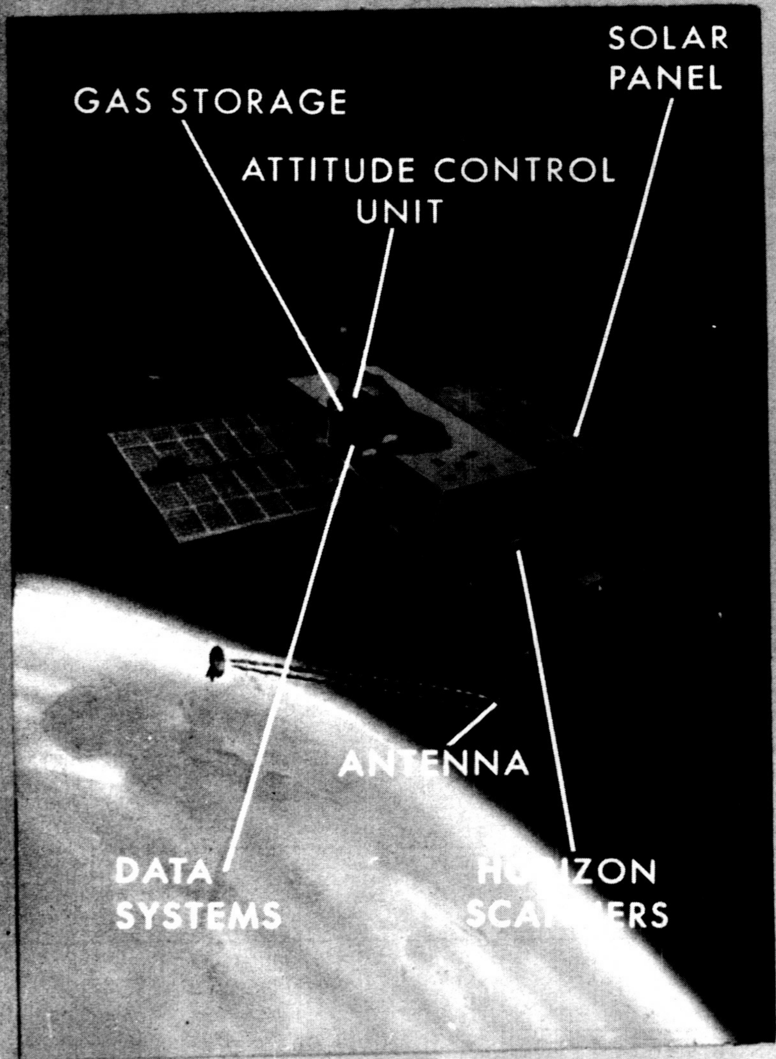
(1964 - Continued)

EXPLORER XXIII	Meteoroid penetration
EXPLORER XXIV	Upper air density and temperature measurements
EXPLORER XXV	Corpuscular radiation and charged particle measurements
MARINER IV	Fly-by Mars in mid-1965; provide data on Martian atmosphere and surface, magnetic fields, cosmic dust.

OSS&A PLANNED FLIGHT SCHEDULE

PROGRAM/PROJECT	LAUNCH VEHICLE	CY 1964 4 Qtr	CY 1965 1	CY 1965 2	CY 1965 3	CY 1965 4	CY 1966 1	CY 1966 2-4
GEOPHYSICS & ASTRONOMY								
OSO	D	X		X				X
OAO	AAG					X		X
OGO	AAG, TAT			X	X		X	X
EXPLORERS	SC, D, TAD	6X	4X	3X	X	3X	2X	6X
LUNAR & PLANETARY								
RANGER	AAG		2X					
SURVEYOR	C			X	X	X	X	X
MARINER	AAG	2X						
PIONEER	TAD				X		X	X
BIOSCIENCES								
BIOSATELLITE	D, TAD						X	3X
METEOROLOGY								
TIROS	D, TAD		X					X
NIMBUS	TAT					X		X
APPLICATIONS TECHNICAL SATELLITE								
ATS	AAG							X
LAUNCH VEHICLES								
CENTAUR DEVELOPMENT	AC	X	2X		X	X		

ORBITING GEOPHYSICAL OBSERVATORY



GROSS WEIGHT	1,000 LBS
INSTRUMENT WEIGHT	150 LBS
INVESTIGATIONS	20/SPACECRAFT
POWER	250 WATTS (AVER)
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	ONE YEAR
LAUNCH VEHICLES	ATLAS-AGENA TAT-AGENA
ORBITS	HIGHLY ELLIPTICAL INCLINED ORBIT NEAR CIRCULAR POLAR ORBIT
STATUS	NEXT FLIGHT-1965

NASA SG64-190
REV. 11/16/64

INSTRUMENTS AND INVESTIGATORS FOR FORTHCOMING MISSIONS

ORBITING GEOPHYSICAL OBSERVATORIES

The Orbiting Geophysical Observatories (OGO) are a series of standardized spacecraft incorporating active three-axis stabilization and capable of accommodating thirty or more scientific investigations in various orbits. Two types are planned:

(1) The eccentric orbiting geophysical observatory will be placed in a highly eccentric orbit reaching from a perigee of 170 miles to an apogee of 92,000 miles. It will be useful for investigations beyond the geomagnetic field, within the field, and within the Van Allen radiation belts.

(2) The polar orbiting geophysical observatory will be launched into near-earth polar orbits (160 to 570 mile polar orbits). It will emphasize the investigation of the phenomena of the polar regions, such as the radiation belt "horns", auroral activity, low energy cosmic rays, the geomagnetic field, the ionosphere, and anomalous temperature and density changes.

The OGO spacecraft weigh approximately 1100 pounds, of which approximately 200 pounds is allotted to investigations. The first Eccentric Orbiting Observatory, OGO-I, was launched with an Atlas Agena on September 4, 1964 from the Eastern Test Range (ETR). OGO-I is not stabilized as planned, but is spin stabilized and is rotating at five revolutions per minute. Data are being received over a considerable portion of its orbit. The first polar orbiting observatory is scheduled for launch with a Thrust-Augmented-Thor-Agena during 1965 from the Western Test Range (WTR).

Spacecraft design, development, fabrication, assembly, integration of investigations, and test and evaluation are being carried out under contract by the TRW-Space Technology Laboratories, Los Angeles, California.

The design for the OGO spacecraft calls for a body of about 31 inches x 33 inches x 67 inches containing portions of the stabilization control, power supply, communications and data handling, and thermal control systems, as well as space for scientific instrumentation. The power supply system consists of solar cell panels, chemical batteries, and a charge control system. A maximum power of 500 watts and an average power of 250 watts will be available. Maximum power allocated to scientific investigations is 80 watts and the average power is 50 watts. Angular orientation of the spacecraft is accomplished through torques developed by motor-driven inertial flywheels and by gas jets. Deviations of the spacecraft from the sun axis are sensed by solar cells; deviations from the earth's local vertical are determined by horizon scanners. Thermal control is accomplished by use of radiation shields and louvers. The data processing and communications system accepts ground commands to program investigations, to vary transmission rates, and to apportion information bits to the data generated by the investigations and by vehicle performance parameters. Storage of 84 million bits of data is possible by use of two magnetic tape recorders. Two redundant wideband telemetry transmitters in the spacecraft are capable of sending scientific and spacecraft engineering data back to earth, either in real time, on command, or from storage.

The following are the final lists of scientific investigations and investigators for OGO's B, C and D. An invitation has been issued for proposals for investigations on OGO-F and an interim selection for OGO-E has been made.

OGO-B

Investigations and Investigators

1. Solar cosmic rays (10-90 Mev) using a scintillation detector to measure fluxes.

   K. A. Anderson
   University of California (Berkeley)

2. Positron and gamma ray detection, using double gamma ray spectrometer to measure positrons (0 to 3 Mev) and to monitor solar photon bursts (30 Kev to 1.2 Mev).

   T. L. Cline, Goddard Space Flight Center
   E. W. Hones, Jr., Institute for Defense Analysis

3. Trapped radiation studies, with ion-electron scintillation detectors; electrons with directional energy flux, 10 Kev $<$ E $<$ 100 Kev and protons with directional intensity, 120 Kev $<$ E $<$ 4.5 Mev.

   A. Konradi, L. R. Davis, R. A. Hoffman and J. M. Williamson
   Goddard Space Flight Center

4. Galactic cosmic rays and isotope abundance with cosmic ray telescope.

   F. B. McDonald and G. H. Ludwig
   Goddard Space Flight Center

5. Low energy galactic cosmic ray flux, using charged particle telescope to study protons above 0.2 Mev and other nuclei at higher energies.

   J. A. Simpson, C. Y. Fan and P. Meyer
   University of Chicago

6. Trapped radiation, using Geiger tubes to measure omnidirectional intensities of outer belt electrons exceeding 40 Kev, 120 Kev, and 1.5 Mev.

   J. A. Van Allen and L. A. Frank
   State University of Iowa

7. Trapped radiation and cosmic radiation, using magnetic electron spectrometer to measure electron energy up to 4 Mev; ionization chamber and geiger counters to monitor trapped radiation and galactic cosmic radiation between 20 Kev and 20 Mev

   J. R. Winckler and R. L. Arnoldy
   University of Minnesota

8. Fluctuations in vector magnetic field (0.01 to 1000 cps) using triaxial search coil magnetometer.

   E. J. Smith
   Jet Propulsion Laboratory

   R. E. Holzer
   University of California (Los Angeles)

9. Measurement of magnitude and direction of magnetic fields (1 to 14,000 gammas) using rubidium vapor and triaxial fluxgate magnetometers.

   J. P. Heppner
   Goddard Space Flight Center

10. Measurement of proton concentrations (10^{-2} to 10^{-4} particles per cm^3) as a function of proton energy (0.2 to 20 Kev) with electrostatic analyzer.

   J. H. Wolfe
   Ames Research Center

11. Study of solar plasma flux using Faraday cup plasma probes to measure plasma flux and energy spectrum, and their variations (10 ev to 10 Kev).

   H. Bridge, A. Bonetti, B. Rossi, A. J. Lazarus, F. Scherb
   Massachusetts Institute of Technology

12. Density and energy distribution of positively and negatively charged particles (0 to 1.0 Kev) using spherical three electrode probe.

R. C. Sagalyn and M. Smiddy
Air Force Cambridge Research Laboratories

13. Densities and energy distributions of charged particles of both polarities in the low energy or thermal range and information on ion masses and fluxes using a planar ion and electron trap.

E. C. Whipple, Jr.
Goddard Space Flight Center

14. Continuous synoptic survey of VLF noise and propatation characteristics (0.2 to 100 Kc/s).

R. A. Helliwell and L. H. Rorden
Stanford University and Stanford Research Institute

15. Brightness distribution of cosmic radio noise over the sky with sweep frequency receiver (2 to 4 Mc/s).

F. T. Haddock
University of Michigan

16. Atmospheric electron content using radio beacon to radiate linearly polarized signals (between 40 and 360 Mc) toward the earth.

R. S. Lawrence and H. J. A. Chivers
National Bureau of Standards (CRPL)

17. Direct measurements of the density of positive ions (1-50 AMU) from 10 to 10^5 ions per cm^3 with RF ion mass spectrometer

H. Taylor and N. W. Spencer
Goddard Space Flight Center

18. Micrometeoroids; vector velocity distribution, cumulative mass distribution, effect of geocentric distance, using piezoelectric detectors, plasma detector, and velocity discriminator.

W. M. Alexander and C. W. McCracken
Goddard Space Flight Center

19. Lyman-alpha scattering in the geocorona to determine the distribution of neutral hydrogen, measured with ion chambers.

P. W. Mange
Naval Research Laboratory

20. Gegenschein photometry in ultraviolet, green and infrared regions with photomultiplier and filter.

C. L. Wolff and K. Hallam
Goddard Space Flight Center

S. P. Wyatt
University of Illinois

OGO's C and D

Investigations and Investigators

1. Brightness distribution of cosmic radio noise over the sky with sweep frequency receiver (2 to 4 Mc/s).

F. T. Haddock
University of Michigan

2. Continuous synoptic survey of VLF noise and propatation characteristics (0.2 to 100 Kc/s).

R. A. Helliwell
Stanford University

L. H. Rorden
Stanford Research Institute

3. Determination of diurnal and latitude variations of VLF spectra in the range 0.5 to 10 Kc/s.

M. G. Morgan and T. L. Laaspere
Dartmouth College

4. Magnetic field fluctuations in the low and sub-audio frequency range from 0.01 to 1000 cps using search coil magnetometers

E. J. Smith
Jet Propulsion Laboratory

R. E. Holzer
University of California (Los Angeles)

5. World magnetic survey with rubidium-vapor and fluxgate magnetometers: 10,000 to 65,000 gammas.

J. P. Heppner and J. C. Cain
Goddard Space Flight Center

6. Monitoring of cosmic radiation and trapped radiation with ionization chamber.

    H. R. Anderson, Jet Propulsion Laboratory
    H. V. Neher, California Institute of Technology

7. Study of low energy protons and nucleons in cosmic radiation and trapped radiation (from 0.3 to 30 Mev) with scintillation telescope.

    J. A. Simpson, E. C. Stone, and C. Y. Fan
    University of Chicago

8. Energy spectrum and charged particle composition of galactic and solar cosmic rays as observed with a modified Cerenkov detector.

    W. R. Webber
    University of Minnesota

9. Net downflux of corpuscular radiation in the auroral zones and over the polar caps, using Geiger tubes as detectors.

    J. A. Van Allen and L. A. Frank
    State University of Iowa

10. Study of fluctuations in the trapped radiation by measuring low energy trapped radiation (electrons, 10-100 Kev; protons, 100 Kev to 4.5 Mev) as observed with scintillation detector.

    A. Konradi, L. R. Davis, R. A. Hoffman, and J. M. Williamson
    Goddard Space Flight Center

11. Photometric airglow measurements at 6300A, 6200A, 5890A, 5577A, 3914A and 2600A using photomultipliers and filters.

    J. Blamont, University of Paris
    E. I. Reed, Goddard Space Flight Center

12. Airglow measurements in the Lyman-alpha and the far ultraviolet between 1230A and 1350A, with ion chambers.

    P.W. Mange, T. A. Chubb and H. Friedman
    Naval Research Laboratory

13. Airglow measurements with ultraviolet spectrometer between 1100A and 3400A.

    C. A. Barth, Jet Propulsion Laboratory
    L. Wallace, Kitt Peak National Observatory

14. Neutral particle and ion composition of the atmosphere (0-6 AMU and 0-40 AMU), with Paul massenfilter mass spectrometer.

L. M. Jones and E. J. Schaefer
University of Michigan

15. Atmospheric positive ion composition and density (1-6 AMU and 7-45 AMU), with Bennett RF ion mass spectrometer.

H. A. Taylor, Jr. and H. C. Brinton
Goddard Space Flight Center

16. Density of neutral atmospheric particles with Bayard-Alpert ionization gage in pressure range from 10^{-5} to 10^{-10} mm Hg.

G. P. Newton
Goddard Space Flight Center

17. Micrometoerites; spatial density, mass distribution, velocity, and charge, in 10^{-13} to 10^{-9} gm range using a combined electrostatic piezoeletric microphone detector.

W. M. Alexander, C. W. McCracken, O. E. Berg, L. Secretan
Goddard Space Flight Center

18. Measurements of electron temperature (800° to 3000°K), of ion or neutral gas temperature (800° to 3000°K) and charged particle density(10^3 to 5×10^6) with a retarding-potential analyzer.

R. E. Bourdeau
Goddard Space Flight Center

19. Time variations in solar X-ray emissions in the 0.5-3A, 2-8A, 8-16A, and 44-60A bands using an ionization chamber.

R. W. Kreplin, T. A. Chubb, H. Friedman
Naval Research Laboratory

20. Monitoring of solar energy (170-1700A) in six ranges using six grating and photocathode combinations.

H. E. Hinteregger
Air Force Cambridge Research Laboratories

OGO-E

Investigations and Investigators

1. Study of distribution of thermal electrons in the magnetosphere with spherical retarding potential analyzers.

   R. L. F. Boyd and A. P. Willmore
   University College, London

2. Detailed description of x-ray and high energy particle features of large solar flares with scintillation detector and proportional counter.

   K. A. Anderson and H. Mark
   University of California, Berkeley

3. Pitch angle and energy measurements of trapped or dumped radiation and other energetic particles using a particle spectrometer.

   R. D'Arcy, L. Mann, and H. West
   Lawrence Radiation Laboratories

4. General study of spatial and temporal distribution of electrons (0.5 to 10 Kev and above 40 Kev).

   L. A. Frank, J. A. Van Allen, and W. A. Whelpley
   State University of Iowa

5. Measurements with a spark chamber to determine possible existence of any preferred directions in the gamma ray component of primary cosmic rays and to detect charged primaries.

   G. W. Hutchinson, D. Ramsden, and R. D. Wills
   University of Southampton, England

6. Monitoring the lower energy galactic cosmic rays and solar proton events with good energy resolution using three counter telescopes.

   F. B. McDonald, G. H. Ludwig, D. E. Hagge, and V. K. Balasubrahmanyan
   Goddard Space Flight Center

7. Six solid state particle detectors for correlation of trapped particle characteristics with hydromagnetic waves.

   P. J. Coleman, Jr., T. A. Farley
   University of California
   (Los Angeles)

   D. L. Judge
   University of Southern California
   and Space Technology Laboratories

8. Vector and scalar magnetic field measurements, to 30,000 gammas, using rubidium vapor and triaxial fluxgate magnetometers.

J. P. Hepper, T.L. Skillman, B.G. Ledley, M.Campbell and M. Sugiura
Goddard Space Flight Center

9. Study of magnetic field fluctuations (0.01 to 1000 cps) with triaxial search coil magnetometers.

E. J. Smith
Jet Propulsion Laboratory

R. E. Holzer
University of California (Los Angeles)

10. High resolution measurements of energetic plasma with electrostatic analyzers and Faraday cups.

C. W. Snyder, M. Neugebauer, and J. L. Lawrence, Jr.
Jet Propulsion Laboratory

11. Observations of low frequency radio bursts from the sun and Jupiter, and cosmic noise (2 Kc/s to 2 Mc/s) with step frequency radiometer.

F. T. Haddock
University of Michigan

12. Distribution of the density of neutral atomic hydrogen and atomic oxygen using UV photometers and 1304A and 1216A wavelengths.

C. A. Barth and J. B. Pearce
Jet Propulsion Laboratory

Further consideration is being given to the following investigations:

13. Measurement of the spatial and temporal variations in the flux and energy distributions of charged particles of thermal energies (from 0 to 2 Kev) with spherical retarding potential analyzers.

R. C. Sagalyn and M. Smiddy
Air Force Cambridge Research Laboratories

14. Density and temperature of ions and electrons (below 100 ev) with planar retarding potential analyzer.

G. P. Serbu and E. J. Maier
Goddard Space Flight Center

15. Studies of low rigidity interplanetary electrons, positrons and protons using scintillation counter telescope.

T. L. Cline
Goddard Space Flight Center

16. Measurement of the flux and energy spectrum of cosmic ray electrons (20 to 100 Mev) with a particle telescope.

P. Meyer and C. Y. Fan
University of Chicago

17. Study of the distribution of electrons (0 to 15 Kev) with triaxial electrostatic analyzers.

K. W. Ogilvie
Goddard Space Flight Center

T. D. Wilkerson
University of Maryland

18. Measure the flux and spectrum of energetic galactic cosmic ray electrons (0.5 to 10 Bev) with particle counter telescope.

A. H. Wapstra
Institute of Nuclear Physics Research, Netherlands

Y. Tanaka, M. N. Lund, Ir. A. Scheepmaker and B. M. Swanenberg
Working Group, Cosmic Radiation, Netherlands

19. Magnetic fields using triaxial fluxgate magnetometer.

P.J. Coleman, Jr. and T. A. Farley
University of California (Los Angeles)

D. L. Judge
University of Southern California and Space Technology Laboratories

20. Determination of the distribution of light ions (H^+, He^+ and O^+) with magnetic mass spectrometer.

G. W. Sharp and T. J. Crowther
Lockheed Missiles and Space Company

21. Determination of spatial density, mass distribution, velocity, and charge of interplanetary dust particles using four particle detectors.

W. M. Alexander, O. E. Berg, C. W. McCracken and L. Secretan
Goddard Space Flight Center

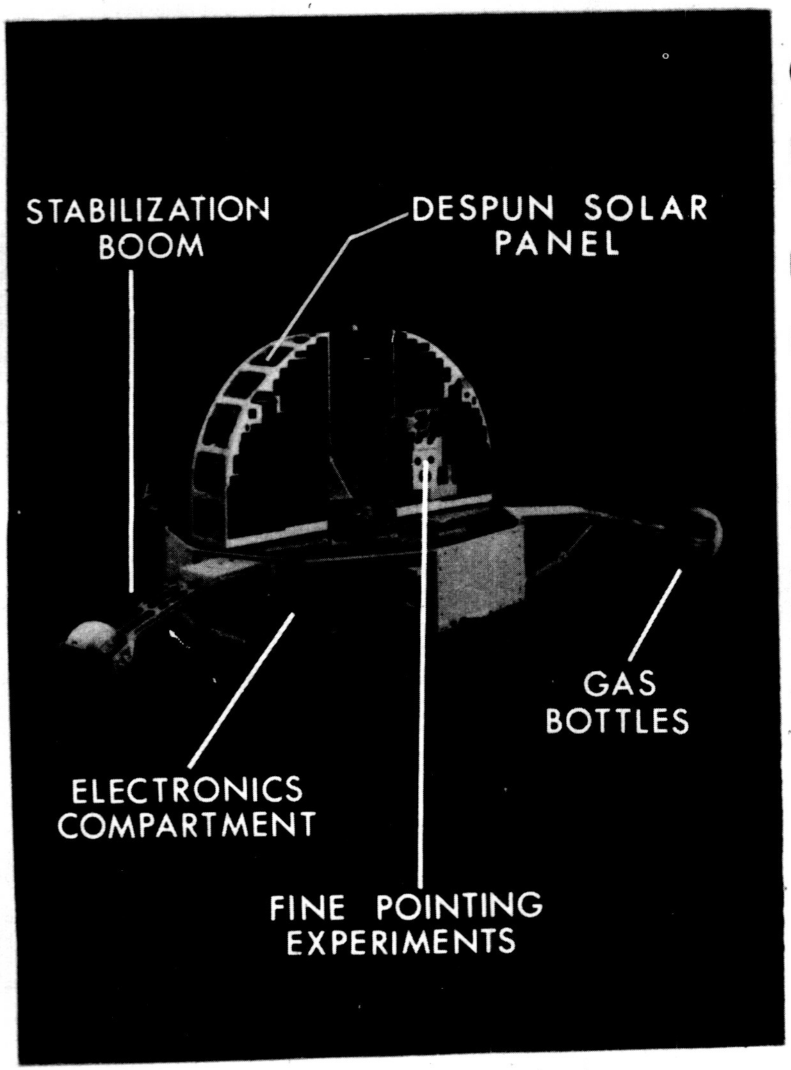
22. Determination of the number density and temperature of hydrogen and deuterium in the geocorona with hydrogen-deuterium cells.

J. E. Blamont
University of Paris

23. Solar radiation monitor.

Investigator to be selected.

ORBITING SOLAR OBSERVATORY



GROSS WEIGHT	540 LBS.
INSTRUMENT WEIGHT	220 LBS.
EXPERIMENTS	13
POWER	26 WATTS (aver.)
STABILIZATION	SPIN
DESIGN LIFE	6 MONTHS
LAUNCH VEHICLE	DELTA
ORBIT	NEAR-EARTH CIRCULAR ORBIT
STATUS	NEXT FLIGHT 4th QUARTER 1964

NASA SG64-192
REV-11-19-64

ORBITING SOLAR OBSERVATORIES

The Orbiting Solar Observatories (OSO) are a series of stabilized space platforms designed to investigate solar phenomena from above the obscuring and distorting effects of the atmosphere. The spacecraft consists of a fan-shaped stabilized section connected by a shaft to a lower rotating wheel-like structure. The wheel contains nine wedge-shaped compartments, five of which are available for scientific instrumentation with the remaining four carrying housekeeping equipment such as the telemetry system and batteries. The oriented portion of the spacecraft, which carries two compartments for scientific instrumentation, points continuously at the center of the sun with an accuracy of somewhat less than 630 minutes of arc. Provision for scanning the sun with a resolution of 1 arc minute can be made available to the experimenters. The wheel investigations are, in general, sky mapping in character, comparing radiation from the sun to that in other portions of the sky. The OSO's will be launched from the Eastern Test Range by Thor-Delta vehciles and are intended to orbit the earth in a circular orbit at an altitude of 350 miles inclined 33 degrees to the equator.

The first Orbiting Solar Observatory (OSO-I) was launched successfully on March 7, 1962 and returned unique data concerning the sun during approximately 10 weeks of tape recorder operation. Real time data was transmitted subsequently until August of 1963, at which time the spacecraft was commanded off. Early in January 1964 the spacecraft was commanded on and returned information on the trapped radiation belt.

The second OSO (OSO-B) was being readied for launch in April 1964 when it was damaged by an unfortunate accident during the mating of the spacecraft to the third stage motor at Cape Kennedy. It has been decided to fly this mission with the refurbished prototype as OSO-B2 in 1964. The third OSO (OSO-C) is scheduled for launch in 1965. Experiments and experimenters for two additional OSO's (OSO's D and E) have been selected and proposals are being received for OSO-F. Following is a list of the experiments and experimenters which have been selected as of 30 September 1964.

OSO-B2

Pointing Section

1. Synoptic measurements of solar UV radiation with UV spectrometer and spectroheliograph (500 to 1500A).

    L. Goldberg, E. M. Reeves, W. H. Parkinson, W. Liller
    Harvard College Observatory

2. Monitoring of solar x-ray bursts, 2-8A, 8-20A, and 44-60A and mapping of x-ray sources.

T. A. Chubb, R. W. Kreplin
Naval Research Laboratory

3. White light coronagraph measurements and UV spectroheliograph solar scan in the Lyman-alpha (1216A, 584A and 304A).

R. Tousey and J. D. Purcell
Naval Research Laboratory

Wheel Section

4. Intensity and direction of the polarized zodiacal light at 4750A to 8500A using photomultipliers and filters.

E. P. Ney, W.F. Huch and R. W. Maas
University of Minnesota

5. Arrival, direction and energies of primary cosmic rays (50-1000 Mev) using lead glass Cerenkov counter.

C. P. Leavitt
University of New Mexico

6. Gamma ray energy spectrum (0.1-3 Mev) and search for solar gamma ray flux, using an anti-coincident shielded gamma ray spectrometer.

K. Frost
Goddard Space Flight Center

7. Ultraviolet stellar and nebular spectra (900-3800A) with objective grating spectrograph.

K. L. Hallam, W. A. White
Goddard Space Flight Center

8. Emissivity stability of surfaces in a vacuum environment.

C. B. Neel, G. G. Robinson
Ames Research Center

OSO-C

Pointing Section

1. Solar extreme ultraviolet flux using a monochromator (60-1300A).

   H. E. Hinteregger
   Air Force Cambridge Research Laboratories

2. X-ray and UV solar spectrum, using spectrometer (1-400A) and x-ray ion chambers (1-8A and 10-20A).

   J. C. Lindsay, W. M. Neupert, W. E. Behring, W. A. White
   Goddard Space Flight Center

Wheel Section

3. Solar and galactic cosmic rays of energies > 3.3 Mev per nucleon with counter telescopes with scintillators and Cerenkov detectors.

   E. M. Hafner, M. F. Kaplon
   University of Rochester

4. Solar x-ray flux (8-20A) using gas-filled ionization chambers, and comparison with optical and radio aspects of sun.

   R. G. Teske
   University of Michigan

5. Earth albedo (1000A-4 microns) using photomultiplier tubes to measure reflected solar radiation.

   C. B. Neel, G. G. Robinson
   Ames Research Center

6. Emissivity stability of low temperature coatings.

   C. B. Neel, G. G. Robinson
   Ames Research Center

7. Celestial x-ray and gamma ray astronomy (15-600 Kev) and study of solar bursts in these frequencies, using Na I scintillation counter.

   L. E. Peterson
   University of California, La Jolla

8. Gamma ray astronomy and search for non-solar gamma ray sources with energies above 100 Mev.

W. L. Kraushaar, G. W. Clark, G. Garmire, R. Baker
Massachusetts Institute of Technology

OSO-D

Pointing Section

1. Measurements of solar flare x-rays with crystal spectrometer to distinguish between emissions from a thermally excited corona and from a relatively low temperature corona.

H. Friedman, T. A. Chubb
Naval Research Laboratory

2. Solar UV spectrum (300-1300A) using normal incidence scanning spectrometer.

L. Goldberg, E. M. Reeves, W. H. Parkinson
Harvard College Observatory

3. Study of solar x-rays, 8-20A, above 20A, and below 8A, using totally reflecting parabolic mirror and detector.

R. Giacconi
American Science and Engineering, Inc.

Wheel Section

4. Survey of non-solar x-ray radiation (0.1-10A) using CsI and SrF_2 detectors.

R. Giacconi
American Science and Engineering, Inc.

5. Distribution of total solar x-ray emission over a wide band, 1.2-3.6A, 3-9A, 6-18A, 44-55A and 44-70A using proportional counters and geiger counters.

E. A. Stewardson, R. L. F. Boyd
Leicester University and University College, London

6. Measurements of charged particles (electrons > 60 Kev and protons > 2 Mev) using a crystal scintillator.

   J. A. Waggoner, S. D. Bloom, C. D. Schrader, R. Kaifer
   University of California, Livermore

7. Solar HeII resonance emission (303.8A) using grating spectrometer and photomultipliers.

   R. L. F. Boyd
   University College, London

8. Measurements of a solar x-ray radiation (8-16A, 2-8A, 0.5-3A, 0.1-1.6A) with four ion chambers.

   T. A. Chubb, R. W. Kreplin, H. Friedman
   Naval Research Laboratory

9. Lyman-alpha night sky glow observed with two ion chamber detectors.

   P. W. Mange, T. A. Chubb, H. Friedman
   Naval Research Laboratory

OSO-E

Pointing Section

1. Solar x-ray (3-9A, 8-18A) using spectroheliograph with proportional counters.

   E. A. Stewardson, R. L. F. Boyd
   University College, London and Leicester University

2. Solar monitoring with extreme ultraviolet spectroheliograph, 1216A, 584A, 304A and probably 335A and 284A.

   J. D. Purcell, R. Tousey, H. Friedman
   Naval Research Laboratory

3. Solar x-ray and UV spectrum using spectrometers (1-400A) and x-ray ion chambers (1-8A and 10-20A).

   J. C. Lindsay, W. M. Neupert, W. E. Behring, W. A. White
   Goddard Space Flight Center

Wheel Section

4. Solar x-radiation 8-16A, 2-8A, 0.5-3A, 0.1-1.6A with ion chamber photometers.

   T. A. Chubb, R. W. Kreplin, H. Friedman
   Naval Research Laboratory

5. Low energy solar gamma rays (5-150 Kev) using scintillation detector.

   K. Frost, H. Horstman, E. Rothe
   Goddard Space Flight Center

6. Monitoring of self-reversal of the solar Lyman-alpha line using photometer with atomic hydrogen absorption cell.

   J. Blamont
   University of Paris

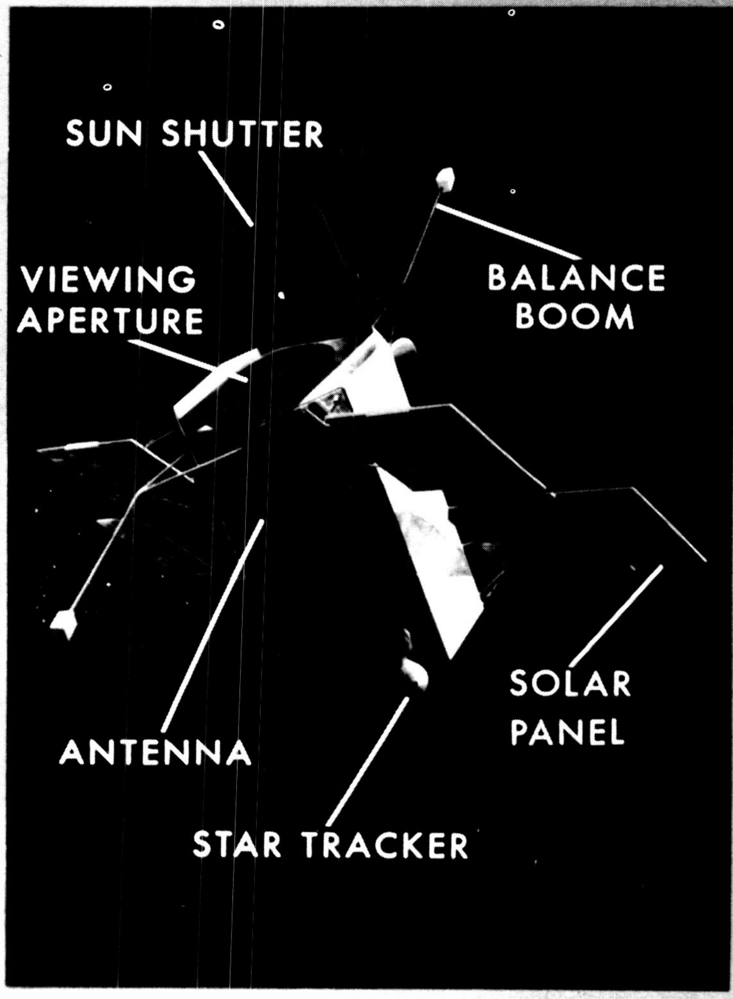
7. Intensity and polarization of the zodiacal light in visible and 1R regions with photomultipliers and polaroid filters.

   E. P. Ney
   University of Minnesota

8. Monitoring of solar far-ultraviolet radiation, 280-370A, 465-630A, 760-1030A with concave grating and photomultiplier.

   W. A. Rense, R. Parker
   University of Colorado

ORBITING ASTRONOMICAL OBSERVATORY



GROSS WEIGHT	- 3,600 LBS
INSTRUMENT WEIGHT	- 1,000 LBS
EXPERIMENTS	- 2 TO 4
POWER	- 400 WATTS (AVER)
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- 1 YEAR
LAUNCH VEHICLE	- ATLAS-AGENA
ORBIT	- CIRCULAR - 434 NM INCLINATION 32°
STATUS	- FIRST FLIGHT 1965

NASA SD63-1450
REV. 11/16/64

ORBITING ASTRONOMICAL OBSERVATORIES

The Orbiting Astronomical Observatories (OAO) are designed to provide an opportunity to explore those regions of the spectrum that are now inaccesible because of atmospheric absorption. The OAO is a precisely-stabilized satellite designed to accommodate various types of astronomical observing equipment. The primary experiments for the first three observatories are concerned with stellar astronomy in the ultraviolet range (800-4000A).

1. OAO-A will carry two prime investigations:

a. A mapping study of the celestial sphere in four ultraviolet ranges. This investigation will map the sky in ultraviolet down to a wavelength of 1200A with four broad band television photometers and will record the brightness of at least 20,000 stars.

b. A broad band photometry study of individual stars and nebulae. These observations will be directed toward the determination of the stellar energy distribution in the spectral region from 1000 to approximately 3000A, and the measurement of emission line intensities of diffuse nebulae in the same spectral region. These investigations are expected to provide data which will not only be useful to the entire astronomical community but will also act as an aid in designing later instrumentation.

2. OAO-B will contain a system designed to obtain absolute spectrophotometric data on selected stars, nebulae and galaxies. The optical system will employ a relatively fast 36-inch Cassegrain telescope with a large aperture spectrophotometer and will use both the coarse (1 minute of arc) and the fine (1 second of arc) control systems. The usable spectral region will be approximately 1000-4000A.

3. OAO-C

a. The absorption investigation in OAO-C has, as its primary objective, quantitative observations of the absorption spectrum of the interstellar gas in the regions between 800 and 3000A.

b. In addition, there are x-ray telescopes to study the sky in the spectral region from 3-60A.

It is expected that later astronomical satellites will be used for studies of the sun and planets. In addition, all astronomical observatories will have a limited amount of payload capacity for small secondary investigations.

The basic OAO structure is octagonally-shaped with a central tubular area containing the experiment equipment. The total weight of the spacecraft is expected to be about 3600 lbs., of which 1000 lbs. is allocated to the experimental apparatus.

The power supply for OAO is externally-mounted fixed arrays of silicon solar cells used in conjunction with rechargeable nickel-cadmium storage batteries. An average power of 400 watts is required by the observatory. The power available to the experimental equipment is to be 30 watts average and 60 watts peak.

The stabilization and control system consists primarily of star trackers, sun trackers, inertial wheels, and gas jets. This system will point the spacecraft in any direction with an accuracy of 1 minute of arc. The experiment optics then will produce an ultimate pointing accuracy of 0.1 second of arc during observation of an individual star. The major function of the attitude control system may be categorized as follows:

1. To stabilize the spacecraft following booster separation and to establish its attitude with the required precision.

2. To slew the satellite to any desired attitude as dictated by the scientific objectives of the mission.

3. To enable the satellite to maintain a given attitude with the required accuracy for long periods of time.

The remainder of the basic system is comprised of data storage units and a communications system, including four radio links which are required to accomplish tracking, command, and telemetry.

The satellite will be launched by an Atlas-Agena from AMR into an approximately-circular orbit at an altitude of 500 statute miles, inclined to the equator at an angle of 32 degrees.

Investigations and Investigators

OAO-A

1. Mapping stellar UV radiation in four ultraviolet ranges, (1200-1550A, 1375-1625A, 1800-2800A, and 2350-2850A) with high resolution telescopes.

   F. Whipple and R. Davis
   Smithsonian Astrophysical Observatory

2. Stellar broad band photometry measurements in ultraviolet, 1000-3000A, in selected portions of sky with filters, telescopes and scanning spectrometers.

   A. D. Code
   University of Wisconsin

OAO-B

1. Absolute spectrophotometry measurements of selected stars and nebulae (1000 to 4000A).

   J. Milligan
   Goddard Space Flight Center

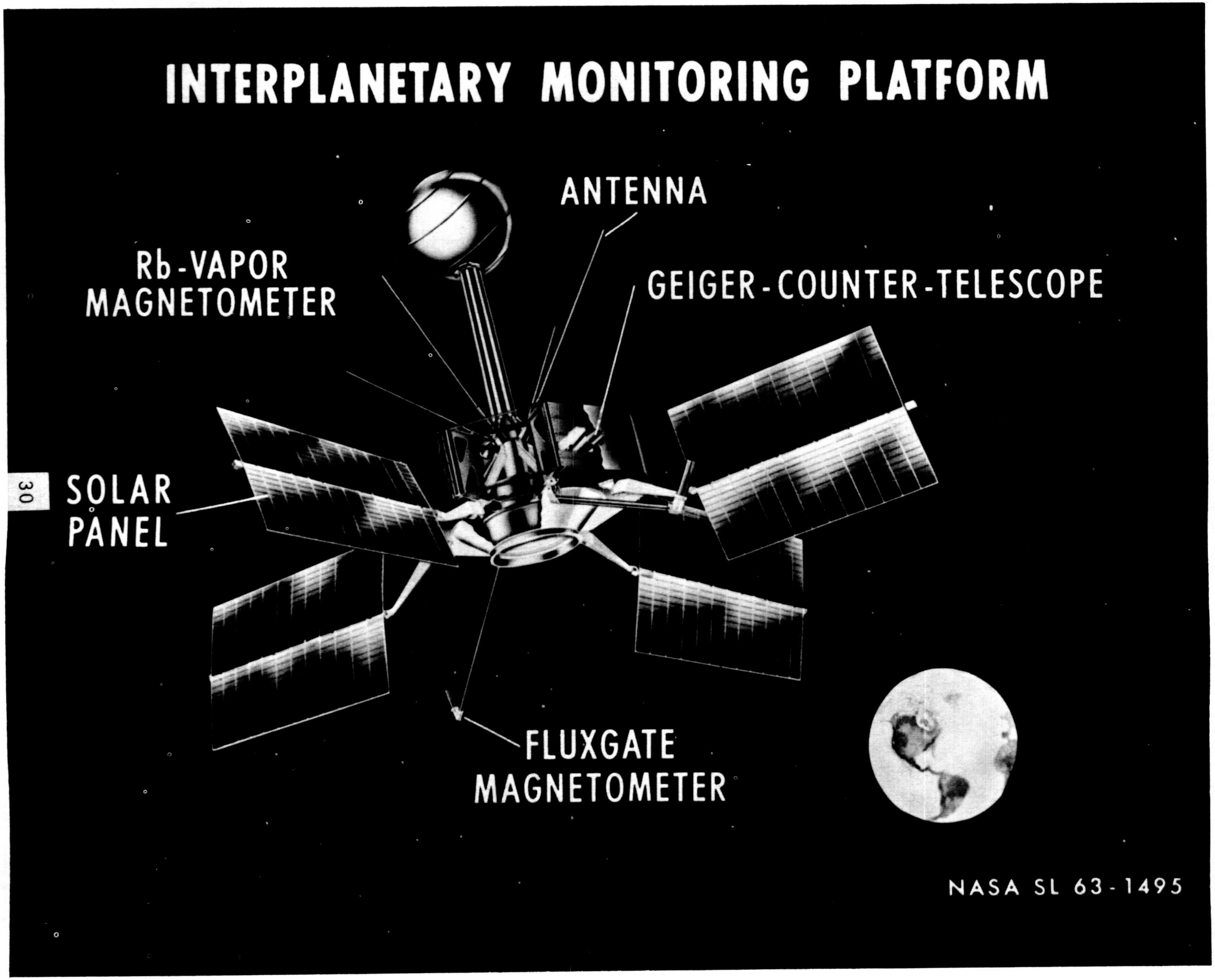
OAO-C

1. Quantitative spectrometer observations of the absorption spectrum of the interstellar gas (800-3000A) using 32 inch reflecting telescope and grating spectrograph.

   L. Spitzer
   Princeton University

2. X-ray emissions of stars and nebulae (3-12A, 8-18A and 44-60A) using reflectors and gas photon counters.

   R. L. F. Boyd
   University College London


INTERPLANETARY MONITORING PLATFORM
ANTENNA
Rb-VAPOR
MAGNETOMETER
GEIGER-COUNTER-TELESCOPE
SOLAR
PANEL
FLUXGATE
MAGNETOMETER
NASA SL 63-1495

INTERPLANETARY EXPLORERS

The interplanetary explorer satellites have been developed for the purposes suggested by their name. They belong to the general group of small satellites and will be put in orbit with the Delta vehicle. The first three have planned orbits with an apogee of 173,000 miles and a perigee of 125 miles and an angle of inclination (33^o). The first three interplanetary explorers carry equipment for the investigations given below. The first two have been launched as Explorer XVIII on November 27, 1963, and Explorer XXI on October 3, 1964.

Investigations and Investigators

IMP-C

1. Magnetic fields measured with rubidium vapor and fluxgate magnetometers.

   N. F. Ness
   Goddard Space Flight Center

2. Plasma flux and energy measurements (a few electron volts to 8 Kev) with Faraday cup plasma probe

   H. S. Bridge and B. Rossi
   Massachusetts Institute of Technology

3. Solar and galactic protons and alpha particles (5 to 200 Mev) using solid state detectors for range vs. energy loss

   J. A. Simpson and G. Gloeckler
   University of Chicago

4. Plasma measurements with planar trap ion-electron detector (0-10 Ev).

   G. P. Servu and R. Bourdeau
   Goddard Space Flight Center

5. Total charged particle flux using ionization and particle detectors to identify and measure energies and pitch angle distributions

   K. A. Anderson
   University of California, Berkeley

6. Total energy of protons versus energy loss (10 to 100 Mev), with crystal and scintillation detectors and Geiger counters

   F. B. McDonald and G. Ludwig
   Goddard Space Flight Center

7. Interplanetary plasma flux and velocity of protons (0.2 to 2 Kev) with curved plate analyzer

   J. H. Wolfe
   Ames Research Center

IMP-D AND IMP-E

The fourth and fifth interplanetary explorers (IMP's D and E) are planned for measurements near the moon and for elliptical lunar orbits with altitudes between 300 and 7000 miles. They will be launched in 1965. The experiments selected for these flights are listed below.

1. Measurement of vector magnetic field from 0 to 200 gammas with closed loop, saturable core fluxgate magnetometers

   C. P. Sonett, J. H. Wolfe, W. J. Kerwin, R. W. Silva
   Ames Research Center

2. Vector magnetic field from 0 to 64 gammas with a triaxial fluxgate magnetometer

   N. F. Ness
   Goddard Space Flight Center

3. Energetic particle flux, protons >0.5, 17 and 50 Mev, electrons >45 Mev, using ion chamber and Geiger tubes.

   K. A. Anderson
   University of California, Berkeley

4. Low energy interplanetary electrons and protons, electrons>40 and >60 Kev and protons, 0.5 to 8 Mev and 0.9 to 3.5 Mev, and alpha particles, 2 to 20 Mev, using GM tubes and solid state detectors.

    J. A. Van Allen
    State University of Iowa

5. Measurement of the ionization, momentum, speed and direction of micro-meteorites using thin film charge detectors, induction devices, and microphones

    J. L. Bohn
    Temple University

    W. M. Alexander and O. E. Berg
    Goddard Space Flight Center

6. Flux of positive and negative charged particles (100 ev to 10 Kev), using retarding potential analyzer

    H. S. Bridge, A. J. Lazarus, and E. F. Lyon
    Massachusetts Institute of Technology

7. Passive observation of unmodified telemetry signal

    A. M. Peterson, V. R. Eshleman, O. K. Garriott, R. L. Leadabrand, and B. B. Lusignan
    Stanford University

8. Selenodesy using analysis of orbits

    W. M. Kaula
    University of California, Los Angeles

9. Lunar ionosphere and radio propagation (on contingent basis if it can be accommodated) using 136 Mc/s and one subharmonic oscillator

    A. M. Peterson, V. R. Eshleman
    O. K. Garriott, B. B. Lusignan
    Stanford University

    R. L. Leadabrand
    Stanford Research Institute

IMP-F AND IMP-C

The fifth and sixth interplanetary explorers (IMP's F and G) are planned for launch in 1966 in eccentric earth orbits with an apogee of about 200,000 miles, a perigee of about 125 miles and an inclination of 33°. The investigations selected are as follows.

1. Integrated ionization from protons of $E > 17$ Mev. and electrons of $E \gtrsim 1$ Mev and X-rays, $E > 100$ Kev with a Neher-type ionization chamber.

   K. A. Anderson
   University of California, Berkeley

   (N.B. Companion Geiger tubes have been approved as a contingent experiment if weight permits for measurement of absolute flux of electrons above 45 Kev and 120 Kev)

2. Scalar magnetic fields using two monoaxial fluxgate magnetometers ($\pm$ 40 gammas) and rubidium vapor magnetometer, 0.1 to 2000 gammas

   N. F. Ness
   Goddard Space Flight Center

3. Cosmic ray anisotropy, protons 10 to 100 Mev, alpha particles 200 to 400 Mev., with particle telescope

   K. G. McCracken, W. C. Bartley, and U. R. Rao
   Graduate Research Center of the Southwest

4. Composition of cosmic rays, protons 0.5 to 85 Mev, $Z \geq 2$ above 6 Mev. per nucleon

   J. A. Simpson and C. Y. Fan
   University of Chicago

5. Flux and energy spectra of hydrogen, deuterium, tritium, and helium with cosmic ray telescope, 12 to 80 Mev per nucleon; also electrons, 1 to 20 Mev.

F. B. McDonald and G. H. Ludwig
Goddard Space Flight Center

6. Particle flux with low energy cosmic ray detector for protons 0.4 to 8 Mev., alpha particles 2 to 8 Mev per nucleon

F. B. McDonald and G. H. Ludwig
Goddard Space Flight Center

7. Energy flux of electrons using retarding potential D. C. scintillator, electrons 0.5 to 15 Kev energy and intensity of electrons, $E > 40$ Kev.

J. A. Van Allen, L. A. Frank, W. A. Whelpley
State University of Iowa

8. Low energy particle telescope, electrons 0.3 to 3.0 Mev.; protons 0.5 to 18 Mev.

W. L. Brown, C. S. Roberts, G. L. Miller
Bell Telephone Laboratories

9. Azimuthal direction of arrival and intensity of protons and electrons with spherical electrostatic analyzer, protons 100 ev - 10 Kev and electrons 5 Kev - 100 Kev

F. B. Harrison and J. L. Vogl
Space Technology Laboratories, Inc.

10. Positive ions up to 10 Kev per unit charge using cylindrical electrostatic analyzer, for $m/z = 1$ and 2.

K. W. Ogilvie
Goddard Space Flight Center

T. D. Wilkerson
University of Maryland

INTERNATIONAL EXPLORERS

This section deals with the satellites that call for international cooperation with national units of scientists or with individual scientists. In this group the second U.S./U.K. cooperative satellite was launched on March 27, 1964, as Ariel II. The Beacon Explorer B, which was launched on October 9, 1964, as Explorer XXII, provides opportunity to scientists around the world to participate in ionosphere studies, and has carried out a successful laser tracking experiment.

UK-E

The UK-E is the third in the series of joint NASA/UK undertakings. Ariel I and Ariel II were both successful. UK-E is to be launched by a Scout vehicle into a near circular orbit of approximately 370 miles altitude, and inclination of 57°. The scientific objectives are to continue the examination of the ionosphere and to continue radio experimentation.

The experiments and investigators are:

1. Continuous measurement of ionization density and temperature.

   J. Sayers
   University of Birmingham

2. Measurement of the vertical distribution of molecular oxygen

   R. Frith
   Meteorological Office, England

3. Mapping large scale noise sources in the galaxy.

   F. G. Smith
   University of Cambridge

4. Radio signals below 20 Kc/s.

   T. R. Kaiser
   University of Sheffield

5. Terrestrial radio noise

J. A. Radcliffe
Radio Research Station

ISIS

The ISIS (International Satellites for Ionospheric Studies) program is a joint NASA/Canadian Defence Research Board undertaking. ISIS is to continue the joint NASA/Canadian program begun with Alouette I by means of a series of ionospheric research satellites for performing studies of the ionosphere from sunspot minimum through sunspot maximum.

ISIS-X

ISIS-X has as objectives both direct measurements in the upper atmosphere and topside soundings of the ionosphere. The program will use the second Canadian-built spacecraft weighing about 300 pounds launched with a Thor-Agena and a separate piggyback spacecraft, weighing about 150 pounds, the U. S. Direct Measurements Explorer. Both will be placed in a near polar orbit with an apogee of about 1800 miles and perigee of about 450 miles.

The experiments are as follows:

Alouette B

1. Topside sounding

J. H. Meek, E. S. Warren, G. L. Nelms
Defence Research Telecommunications Establishment

2. Measurement of energetic particles

D. C. Rose and I. B. McDiarmid
Canadian National Research Council

3. Study of very low frequency (VLF) propagation

R. E. Barrington
Defence Research Telecommunications Establishment

4. Cosmic radiofrequency noise

T. R. Hartz
Defence Research Telecommunications Establishment

5. Electrostatic probe

L. H. Brace
Goddard Space Flight Center

Direct Measurements Explorer-A

1. Densities and temperatures of positive and negative ions with planar ion probe

   R. Bourdeau, J. L. Donley
   Goddard Space Flight Center

2. Total current at a collector mounted flush with satellite skin

   R. Bourdeau, J. L. Donley
   Goddard Space Flight Center

3. Electron density and temperature with Langmuir probe

   L. H. Brace
   Goddard Space Flight Center

4. Electron temperature using planar probe

   A. P. Willmore
   University College, London

5. Ion temperature and density with spherical ion mass spectrometer.

   R. L. Boyd and A. P. Willmore
   University College, London

6. Particles in mass range, 1-32 AMU with high resolution magnetic mass spectrometer.

   J. H. Hoffman
   Naval Research Laboratory

7. Energetic electron current monitor

   E. J. Maier
   Goddard Space Flight Center

ISIS-A

ISIS-A is to be launched by an improved Delta into a low altitude, near polar orbit with a perigee of approximately 300 miles, apogee of 3800 miles, and inclination of 80°.

The experiments and investigators are:

1. Electron density using sweep frequency sounder (0.1 to 16 Mc/s)

   J. H. Chapman
   DRTE, Canada

2. Small irregularities in ionsphere with fixed frequency sounder

   J. H. Chapman, DRTE, Canada
   W. Calvert, T. E. Van Zandt, CRPL
   G. L. Nelms, L. E. Petrie, DRTE

3. Integrated electron content with radio beacon operating at 40, 41, and 136 Mc/s

   J. H. Chapman, DRTE, Canada
   J. L. Jesperson, NBS, CRPL
   P. A. Forsyth, G. L. Lyon, E. H. Tull, University of Western Ontario

4. Monitoring of background cosmic radio noise using sweep frequency receiver

   T. R. Hartz
   DRTE, Canada

5. ELF/VLF emissions from upper atmosphere, using receiver sensitive to 0.05 to 30 Kc/s

   J. S. Belrose
   DRTE, Canada

6. Study of positive and negative particles in three overlapping ranges, 10 ev to 10 Kev, using electrostatic detector.

W. J. Heikkila
Graduate Research Center of the Southwest

7. Electron temperature and density with two cylindrical Langmuir probes.

L. H. Brace
Goddard Space Flight Center

8. Energetic charged particles in lower part of outer radiation belt using geiger counters for electrons, 40-780 Kev, and silicon junction detectors for protons, 100 Kev to 63 Mev.

I. B. McDiarmid, D. C. Rose, J. R. Burrow, E. E. Budzinski
National Research Council of Canada

9. Positive ion density and temperature using spherical ion retarding potential analyzer in altitude range, 1000 to 3500 Km.

R. C. Sagalyn, M. Smiddy
Air Force Cambridge Research Laboratories

10. Positive ion measurements with ion mass spectrometer with mass range of 1 to 20 A.M.U. and density range from 5 to 5 x 10^5 ions/cm^3.

R. S. Narcisi, A. D. Bailey
Air Force Cambridge Research Laboratories

ESRO

There are two ESRO (European Space Research Organization) projects planned. These are co-operative international projects whereby ESRO will provide the spacecraft and experiments and NASA will provide the launch vehicle and launch support.

ESRO I

ESRO I is to be launched by a Scout into a polar eccentric orbit with perigee of about 175 miles, apogee about 950 miles, and inclination of 90°. The scientific objective is an integrated study of high latitude energetic particles and their effects on the polar ionosphere. The payload will include a beacon experiment for measurements of the total electron content between the satellite and ground observers.

The experiments and investigators are:

1. Corpuscular radiation

   O. E. Petersen
   Technical University, Denmark

   W. Riedler
   Kirùna Geophysics Observatory, Norway

   R. Dalziel
   Radio Research Station, England

2. Electron temperature and density

   A. P. Willmore
   University College, London, England

3. Ion Composition

   A. P. Willmore
   University College, London, England

4. Auroral Photometry

   A. Omholt
   University of Oslo

   D. R. Bates
   Queen's University, Belfast

ESRO II

ESRO II is to be launched by a Scout into a polar eccentric orbit with perigee of about 200 miles, apogee of about 750 miles, and inclination of 98°.

The scientific areas of ESRO II are solar radiation and cosmic rays.

The experiments and investigators are:

1. Solar X-rays.

   E. A. Stewardson and K. A. Pounds
   University of Leicester

   R. L. F. Boyd and J. L. Culham
   University College, London

   C. de Jager and W. de Graaff
   Sterrewacht, Utrecht

2. Trapped radiation

   H. Elliot and J. J. Quenby
   Imperial College, London

3. Solar and Van Allen Belt Protons

   H. Elliot and J. J. Quenby
   Imperial College, London

4. Cosmic ray protons and alpha particles

   H. Elliot and J. J. Quenby
   Imperial College, London

5. High energy electrons

   P. L. Marsden
   University of Leeds

6. Solar and cosmic ray protons

   J. Labeyrie and L. Koch
   Saclay, France

FR-I

This program represents French and U.S. cooperation in space research. The program has as objectives to launch two French-built satellites to measure very low frequency (VLF) wave propagation in the E and H vector fields in circular orbits at about 500 miles altitude. The experiments will make the following measurements.

1. Three components of the magnetic field.

2. Two orthogonal components of the electric field

3. Antenna impedance

4. Electron density

SAN MARCO

The San Marco program is a cooperative effort of Italy and the United States. The primary purpose is a direct, continuous measurement of atmospheric density in the equatorial region in the altitude range between 120 and 240 miles by means of atmospheric drag on the satellite. A secondary purpose is determination of the electron content between the satellite and earth. The spacecraft will consist of two spherical shells, one within the other. Motion of one relative to the other will be measured with displacement transducers arranged on three orthogonal axes to secure the atmospheric drag on the outer sphere. The experiments and experimenters are as follows:

1. Atmospheric parameters by means of strain gage drag balance between two concentric spheres.

   L.Broglio
   University of Rome, Italy

2. Integrated electron content with radio beacon at 20 Mc/s.

   N. Carrara
   Microwave Center, Florence, Italy

Air Density/Injun *

The Air Density/Injun payload consists of two independent spacecraft to be launched simultaneously by a Scout into a near polar, eccentric orbit with perigee of about 300 miles, apogee of 1500 miles, and inclination of 82°. The Air Density spacecraft is a 12-ft. sphere of the same design as Explorers IX and XIX. Like Explorers IX and XIX, it will be used to study changes in atmospheric density through the changes in drag as shown by orbital changes. The Injun spacecraft is designed to make direct measurements of the down flux of corpuscular radiation into the atmosphere with CsI and CdS detectors, Geiger counters, and spherical retarding potential analyzers. The flux will be correlated with changes in atmospheric density.

The investigators are:

AIR DENSITY EXPLORER

1. Systematic changes in atmospheric density from atmospheric drag

   W. J. O'Sullivan, C. Coffee, G. Keating
   Langley Research Center

2. Non-systematic changes in atmospheric density

   L. Jacchia
   Smithsonian Astrophysical Observatory

INJUN

1. Downflux of corpuscular radiation (electrons 0 - 2.2 Mev, protons 0 - 40 Mev) using a variety of radiation detectors (Van Allen) and measurements of low energy ions and electrons (0 - 1.3 Kev) with spherical retarding potential analyzer (Sagalyn)

J. Van Allen	R. Sagalyn
State University of Iowa (Injun Spacecraft)	Air Force Cambridge Research Laboratories

* Launched on November 21, 1964, as Explorer XXIV (Air Density Explorer) and Explorer XXV (Injun Explorer).

Atmosphere Explorer AE-B

A second Atmosphere Explorer, similar to Explorer XVII, launched on April 2, 1963, is planned for launch in 1965 to study the neutral atmosphere. It is a stainless steel, vacuum tight 35-inch sphere, designed to avoid atmospheric contamination. The experimentation is as follows:

1. Electron densities between 10^3 per cm^3 and 4×10^6 per cm^3 with swept voltage electron probe

    L. Brace
    Goddard Space Flight Center

2. Partial densities of neutral gases using double focusing neutral mass spectrometer (1,4,14,16,18,28, and 32 AMU)

    C. Reber and J. E. Cooley
    Goddard Space Flight Center

3. Direct measurement of atmospheric pressures, 10^{-6} to 10^{-10} mm. Hg, densities, and temperatures, with three Redhead gages

    G. P. Newton
    Goddard Space Flight Center

4. Distribution of ions in the upper atmosphere with radiofrequency 3-stage ion mass spectrometer (0.5 - 2.5, 3.5 - 4.5, and 13 - 19 AMU)

    H. A. Taylor, H. C. Brinton, R. A. Pickett
    Goddard Space Flight Center

Energetic Particles Explorer EPE-D

Another Energetic Particles Explorer is planned for 1964, similar to Explorer XV, launched October 27, 1962, to study the enhanced radiation belt. Like its predecessor, it will be placed in an orbit with apogee of about 10,000 miles and perigee of about 175 miles. Instrumentation in the two is much the same.

1. Energy of particles and angular distribution, with different silicon particle detectors.

    W. Brown
    Bell Telephone Laboratories

2. Energy of particles, electrons > 3.5 Mev and protons > 35 Mev, with plastic scintillator and angular distribution of electrons with $E > 0.5$ Mev and $E > 0.8$ Mev

   C. McIlwain
   University of California, San Diego

3. Magnetic fields between 1.7 and 3.5 earth radii with two-axis saturable core magnetometer

   L. Cahill, Jr.
   University of New Hampshire

4. Particle fluxes with ion-electron scintillation counter

   L. R. Davis
   Goddard Space Flight Center

5. Study of damage to n-on-p silicon solar cells

   L. Slifer
   Goddard Space Flight Center

PAGEOS AND GEOS

In the National Geodetic Satellite Program both active and passive Explorer satellites are being developed. The program objectives are to improve the accuracy of geocentric positions of geodetic datum points. The passive satellite, PAGEOS, will be flown in a near circular, polar orbit at an altitude of about 2300 miles. The active satellites, GEOS-A and B, will be placed in orbits with a perigee of about 690 miles, apogee of 690 to 920 miles, and inclinations of 59° and 80°, respectively. Three government agencies will be the main participants in the program -- the Department of Commerce, the Department of Defense, and NASA. The international geodetic community will be invited to participate in the planning and establishment of a cooperative observing network.

Six satellite geodesy systems are to be utilized. The systems and experimenters are as follows:

1. S-band range and range rate.

   John Berbert
   Goddard Space Flight Center

2. Optical beacon

   George Hadigeorge
   Air Force Cambridge Research Laboratories

3. Passive satellite triangulation

   Captain L. W. Swanson
   U.S. Coast and Geodetic Survey

4. SECOR

   J. McCall
   Army Corps of Engineers

5. Laser reflector tracking.

   H. Plotkin
   Goddard Space Flight Center

6. Doppler

   LCdr. C. J. Limerick, Jr.
   Bureau of Naval Weapons

NASA is selecting investigators for the following investigations.

1. Gravimetric geodesy.

2. Geometric geodesy.

3. Correlation and evaluation of geodetic satellite measurement techniques.

Balloons

The following investigations are scheduled to be conducted from balloons.

1. Measurement of the low energy proton and electron content of the primary cosmic radiation

   P. Meyer
   University of Chicago

2. Measurement of charge spectra of the primary cosmic radiation

   E. Palmatier
   University of North Carolina

3. Detection of Bremsstrahlung X-rays during auroral displays

   L. Cahill, Jr.
   University of New Hampshire

4. High energy particles X-rays, and electron precipitation in the auroral zone

   K. A. Anderson
   University of California, Berkeley

5. Micrometeorite collection during meteor showers

   C. Hemenway
   Dudley Observatory

6. Measurement of anisotropy of gamma rays (3 - 30 Mev)

   G. Clark
   Massachusetts Institute of Technology

7. Measurement of cosmic ray anisotropies

   K. G. McCracken
   Graduate Research Center of Southwest

8. Photography of K-corona by means of an occulted coronagraph

   G. Newkirk
   University Corporation for Atmospheric Research

9. X-ray and gamma ray measurements

L. Peterson
University of California, La Jolla

10. "Project Stratoscope" Observations of stars

M. Schwarzschild
Princeton University

11. Collection and analysis of large samples of interplanetary dust

J. Arnold
University of California, San Diego

X-15

The X-15 A-2, a redesigned version of the original X-15, has been equipped with an instrument bay back of the cockpit with hinged doors that can be opened for scientific experimentation. The bay is equipped with a stabilized platform capable of supporting approximately ninety pounds of scientific payload and of maintaining pointing accuracy to within 0.5 minutes of arc. The following experiments are scheduled for flight.

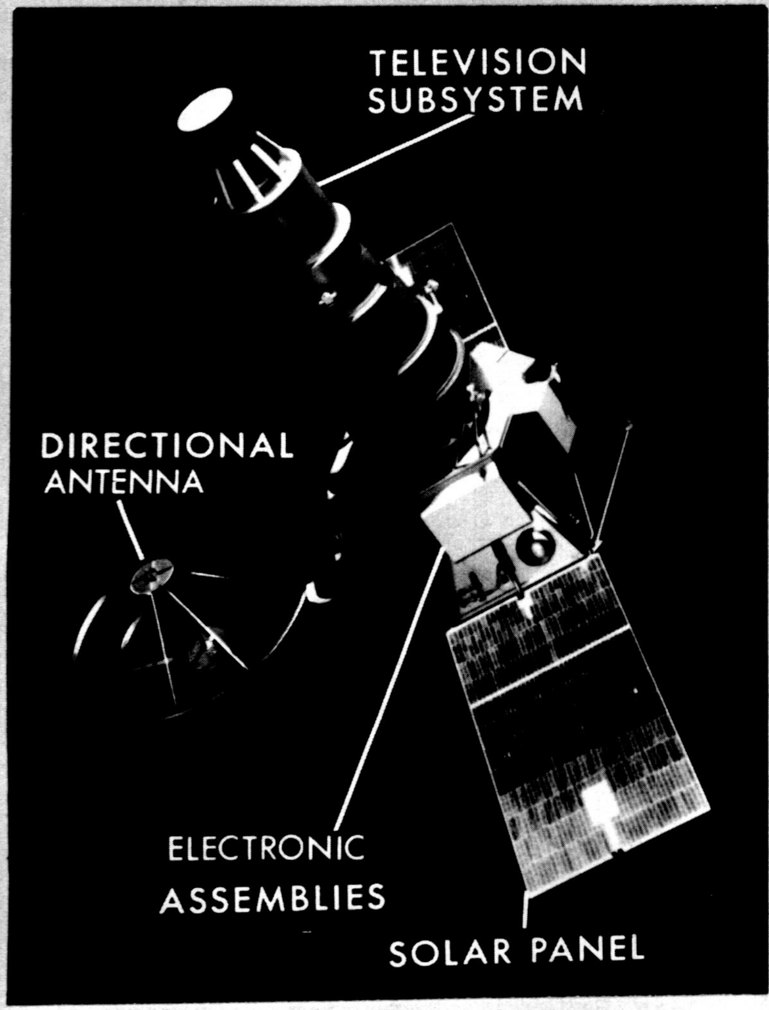
1. Ultraviolet stellar photographic photometry at 2100 A, 2600 A, 4200 A and stellar spectra in range 1800 - 3000 A

A. D. Code, T. E. Houck, T. Bless, J. McNall, D. Schroeder
University of Wisconsin

2. Photometry to measure relative brightness of sky and earth background

A. D. Code
University of Wisconsin

RANGER (6-9)



GROSS WEIGHT	- 807 LBS.
INVESTIGATIONS	- 6 TV CAMERAS
TELEVISION SUB-SYSTEM WEIGHT	- 375 LBS
POWER	- 170 WATTS
PROPULSION	- MIDCOURSE MOTOR-(LIQUID)
STABILIZATION	- ACTIVE 3 AXIS
LIFE	- 66 HR TRANSIT
LAUNCH VEHICLE	- ATLAS AGENA-B
TRAJECTORY	- LUNAR IMPACT VIA PARKING ORBIT
STATUS	- NEXT FLIGHT, 1ST QUARTER 1965

NASA SD63-1455
REV. 11/16/64

RANGER

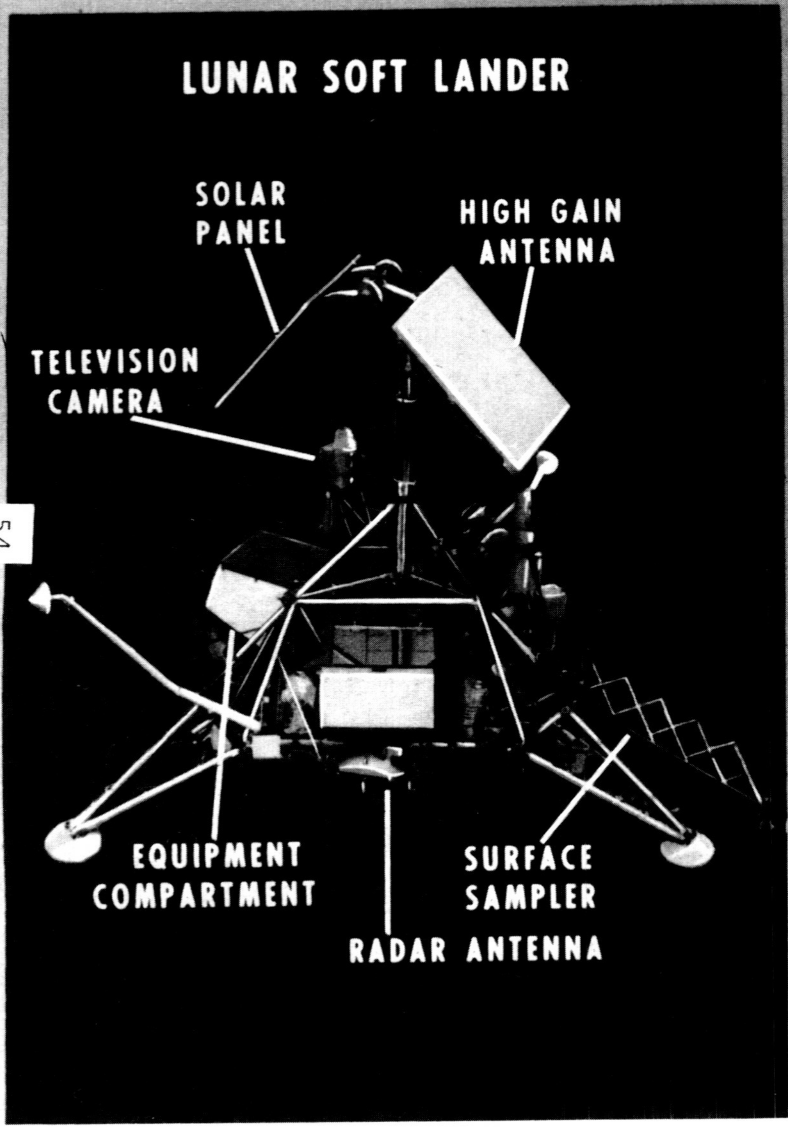
The prime investigation on the current RANGERS will be a wide bandwidth, high resolution television system for obtaining close-up pictures of the moon during the final approach before impact on the surface. The pictures are expected to be an order of magnitude better in resolution than those obtained by earth-based techniques. The RANGER system will begin taking pictures at about 1000 miles from the surface and will resolve lunar features as small as three feet in the last pictures before impact.

RANGER VI was launched in January 1964 but failed to accomplish its mission due to a failure in the TV subsystem. RANGER VII, launched in July 1964, was an unqualified success. More than 4000 high quality photographs were returned to earth. The final pictures had a resolution in excess of 2000 times better than those previously obtained through earth-based telescopes.

RANGERS C and D, which will carry the same payload as was flown on RANGERS VI and VII, are scheduled for launch early in 1965. Experimenters will be as follows:

G. P. Kuiper	(Arizona)
H. C. Urey	(UCSD)
E. Shoemaker	(USGS)
R. Heacock	(JPL)
E. Whitaker	(Arizona)

SURVEYOR



GROSS WEIGHT	- 2,250 LBS
INSTRUMENT WEIGHT	- 114 LBS
INVESTIGATIONS	- 6
POWER	- 88 WATTS
STABILIZATION	- ACTIVE 3 AXIS
PROPULSION	
RETROROCKET	- SOLID
VERNIER ROCKETS	- LIQUID
DESIGN LIFE	- 30-90 DAYS
LAUNCH VEHICLE	- ATLAS-CENTAUR
TRAJECTORY	- DIRECT ASCENT OR PARKING ORBIT
STATUS	- FIRST FLIGHT 1965

NASA SD63-1456
REV. 11/16/64

SURVEYOR

Surveyor is the NASA lunar exploration program concerned with the soft landing of unmanned instrumented spacecraft on the Moon. The following list of investigations has been selected for the first several operational missions:

1. Television - visual surveillance of lunar surface topographic and terrain features.

E. M. Shoemaker	(USGS)
G. P. Kuiper	(Arizona)
E. Whitaker	(Arizona)
J. J. Rennilson	(JPL)
E. Morris	(USGS)
R. Altenhofer	(USGS)

2. Micrometeorite Ejecta - determine flux, velocity, and mass distribution of material ejected from lunar surface by meteoritic impacts.

W. M. Alexander	(GSFC)
O. E. Berg	(GSFC)
L. Secretan	(GSFC)
C. W. McCracken	(GSFC)

3. Seismometer - single-axis short-period seismometer to investigate lunar seismic activity on Moon.

G. H. Sutton	(Lamont)
M. Ewing	(Lamont)
F. Press	(CIT)

4. Alpha Scattering - elemental analysis of lunar surface material.

A. Turkevich	(Chicago)
J. Patterson	(Argonne National Laboratory)
E. Franzgrote	(JPL)

5. Surface Sampler/Soil Mechanics - determines surface structure and mechanical properties of lunar surface material.

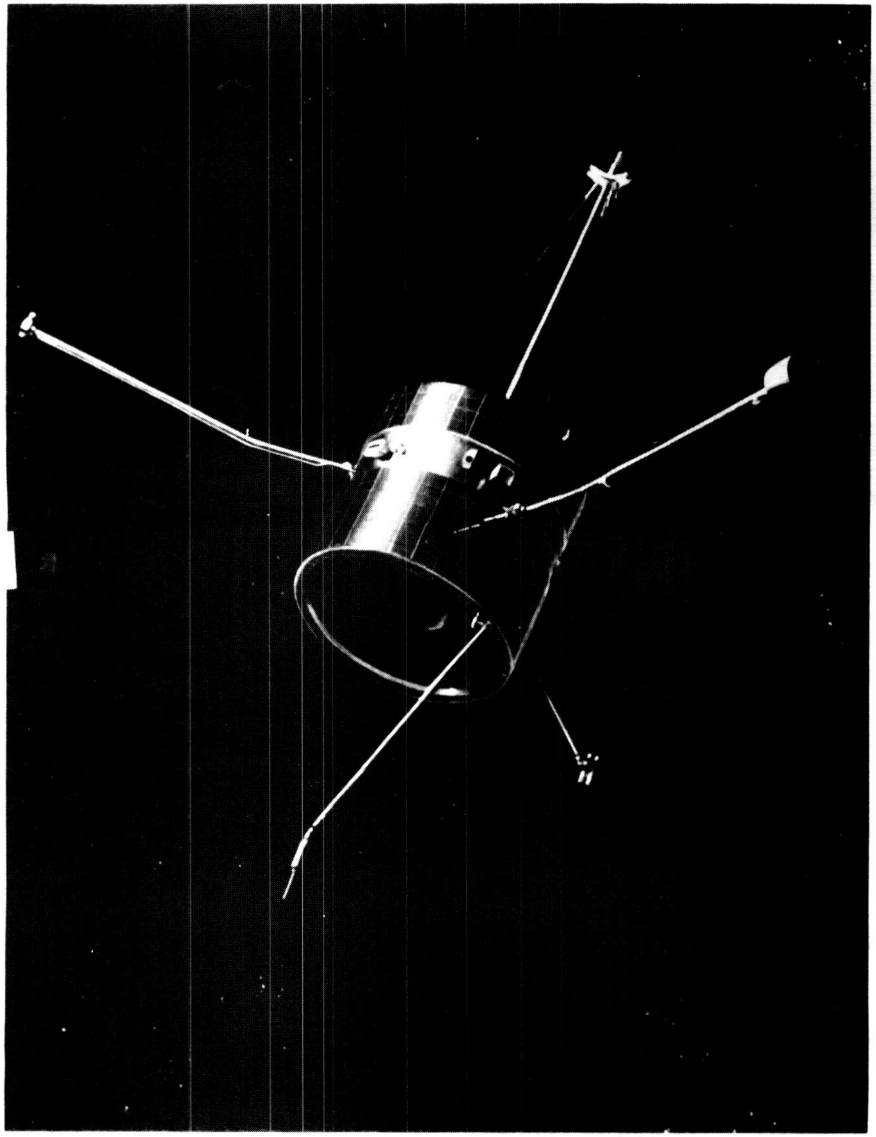
R. F. Scott	(CIT)
R. M. Haythornwaite	(Michigan)
R. A. Liston	(U.S. Army Ordnance Land Locomotion Laboratory)

6. Touchdown Dynamics - determines mechanical properties of lunar surface material.

S. A. Batterson (Langley Research Center)

The Surveyor Program will assist the Apollo Program by providing topographic and lunar surface bearing strength information needed to certify suitable landing sites.

PIONEER



GROSS WEIGHT	- 140 LBS
INSTRUMENT WEIGHT	- 30 LBS
INVESTIGATIONS	- 6
POWER	- 50 WATTS
STABILIZATION	- SPIN
DESIGN LIFE	- 6 MONTHS
LAUNCH VEHICLE	- THRUST AUGMENTED IMPROVED DELTA
TRAJECTORY	- INTERPLANETARY
STATUS	FIRST FLIGHT 1965

NASA SD63-1453
REV. 11/16/64

PIONEER

NASA, beginning in 1965, will launch a series of spacecraft, designated Pioneer to monitor interplanetary space during and following the International Quiet Sun Year. The scientific payload for Pioneers A & B is as follows:

1. Magnetometer - measures the interplanetary magnetic field.

   N. F. Ness (GSFC)

2. Plasma Probe - Faraday cup with split collector measures the characteristics of the interplanetary plasma including the flux, energy spectrum, direction, and angular distribution of positive ions and electrons.

   H. S. Bridge (MIT)

   A. J. Lazarus (MIT)

   F. Scherb (MIT)

3. Cosmic Ray Telescope - measures proton and alpha particle fluxes and energy spectra.

   J. A. Simpson (Chicago)

   J. Lamport (Chicago)

   C. Y. Fan (Chicago)

4. Radio Propagation Investigation - measures the interplanetary electron density and its variation.

   V. R. Eshleman (Stanford)

   O. K. Garriott (Stanford)

   R. L. Leadabrand (SRI)

   A. M. Peterson (SRI & Stanford)

5. Cosmic Ray Detector - studies the lower energy portion of cosmic ray spectrum to determine degree and variations of anisotropy.

K. G. McCracken	(SW Graduate Res. Center)
W. C. Bartley	(SW Graduate Res. Center)
U. R. Rao	(SW Graduate Res. Center)

6. Plasma Probe - curved plate electrostatic particle detector measures characteristics of the interplanetary plasma including the flux, energy spectrum, direction, and angular distribution of positive ions and electrons.

J. H. Wolfe	(Ames)
R. W. Silva	(Ames)

PIONEER C AND D PAYLOAD

1. Magnetometer - a three-orthogonal component fluxgate magnetometer, each sensor having a dynamic range of ± 200 gamma and a sensitivity of 0.2 gamma.

C. P. Sonett (Ames Research Center)

W. J. Kerwin (Ames Research Center)

2. Plasma Probe - a quadrispherical electrostatic analyzer employing eight separate current collectors to provide angular distribution in the polar meridian plane. Energy coverage is from 200 ev to 16 kev in two sets of ranges for protons and 3 ev to 1 kev for electrons.

J. H. Wolfe (Ames Research Center)

R. W. Silva (Ames Research Center)

3. Cosmic Ray Telescope - a time multiplexed triple purpose telescope to measure the intensity and energy spectrum of protons; alpha particles and heavier nuclei in the range 1 Mev to greater than 1 Bev.

W. Webber (University of Minnesota)

G. Bingham (University of Minnesota)

4. Cosmic Ray Detector - high and low counting rate detectors capable of resolving the anisotropy in the galactic and solar cosmic radiation.

K. G. McCracken (Graduate Res. Ctr. of the Southwest)

W. C. Bartley (Graduate Res. Ctr. of the Southwest)

U. R. Rao (Graduate Res. Ctr. of the Southwest)

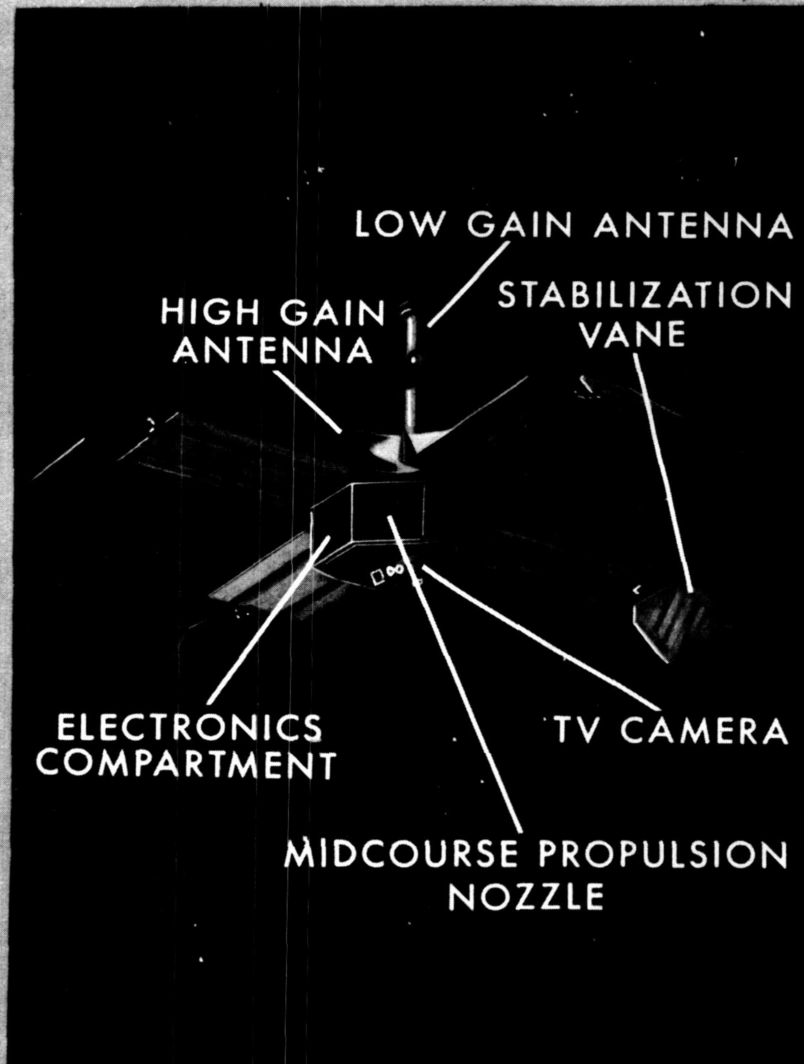
5. Radio Receivers - two receivers, one at 50 Mc/s and the other at 400 Mc/s for receiving signals transmitted by two transmitters (30 and 300 kw) emitted from the Stanford 150 foot steerable parabolic dish; for measuring average interplanetary electron density between the Earth and the probe and its time variations.

V. R. Eshleman	(Stanford University)
O. K. Garriott	(Stanford University)
A. M. Peterson	(Stanford University)
R. L. Leadabrand	(Stanford University)
B. B. Lusignan	(Stanford University)

6. Cosmic Dust Detector - composed of four sensors mechanically and electrically constructed to measure the particle time of flight, approximate radiant, impact impulse and cross section of impact crater to determine mass, density, and orbits of dust particles.

W. M. Alexander	(GSFC)
O. E. Berg	(GSFC)
C. S. Nilsson	(GSFC)
L. Secretan	(GSFC)

MARINER MARS



GROSS WEIGHT	- 575 LBS
INSTRUMENT WEIGHT	- 40 LBS
INVESTIGATIONS	- 8
POWER	- 150 WATTS
STABILIZATION	- ACTIVE 3 AXIS
DESIGN LIFE	- 9 MONTHS
LAUNCH VEHICLE	- ATLAS-AGENA
TRAJECTORY	- INTERPLANETARY, MARS FLY-BY
STATUS	- TWO FLIGHTS 4TH QUARTER 1964

NASA SD63-1454
REV. 11/16/64

MARINER*

Mariners C and D will be launched in connection with the 1964 Mars opportunity, and following successful launch will assume the appropriate Roman numeral designation. These two identical spacecraft are designed to perform scientific measurements in interplanetary space between the orbits of Earth and Mars and in the vicinity of Mars. Their payloads are comprised of the following:

1. Television - photographs a band on the Martian surface with a number of overlapping alternately red and green filtered 3 kilometer resolution pictures.

R. B. Leighton	(CIT)
B. C. Murray	(CIT)
R. P. Sharp	(CIT)

2. Magnetometer - measures the interplanetary magnetic field and the Martian field, if detectable at fly-by distance, using a sensitive 3-axis helium magnetometer.

E. J. Smith	(JPL)
P. J. Coleman, Jr.	(UCLA)
L. Davis	(CIT)
D. E. Jones	(Brigham Young)

3. Occultation - measures Martian atmospheric properties from the radio signal variations as the spacecraft passes behind Mars.

A. J. Kliore	(JPL)
D. L. Cain	(JPL)
F. D. Drake	(Cornell)
V. R. Eshleman	(Stanford)
G. S. Levy	(JPL)

*Mariner C was launched as Mariner III on November 5, 1964. This flight was not a success. Mariner D was launched successfully as Mariner IV on November 28, 1964.

4. Plasma Probe - measures the character of the interplanetary plasma including flux, energy, and direction of protons.

H. S. Bridge	(MIT)
A. J. Lazarus	(MIT)
C. W. Snyder	(JPL)

5. Cosmic Ray Telescope - determines flux and energy spectrum of low, medium and high energy protons and alpha particles using silicon solid-state detectors.

J. A. Simpson	(Chicago)
J. O'Gallagher	(Chicago)

6. Low Energy Cosmic Ray - studies the angular distributions, energy spectra and time histories of solar cosmic rays and energetic electrons in interplanetary space and in the vicinity of Mars.

J. A. Van Allen	(SUI)
L. A. Frank	(SUI)
S. M. Krimigis	(SUI)

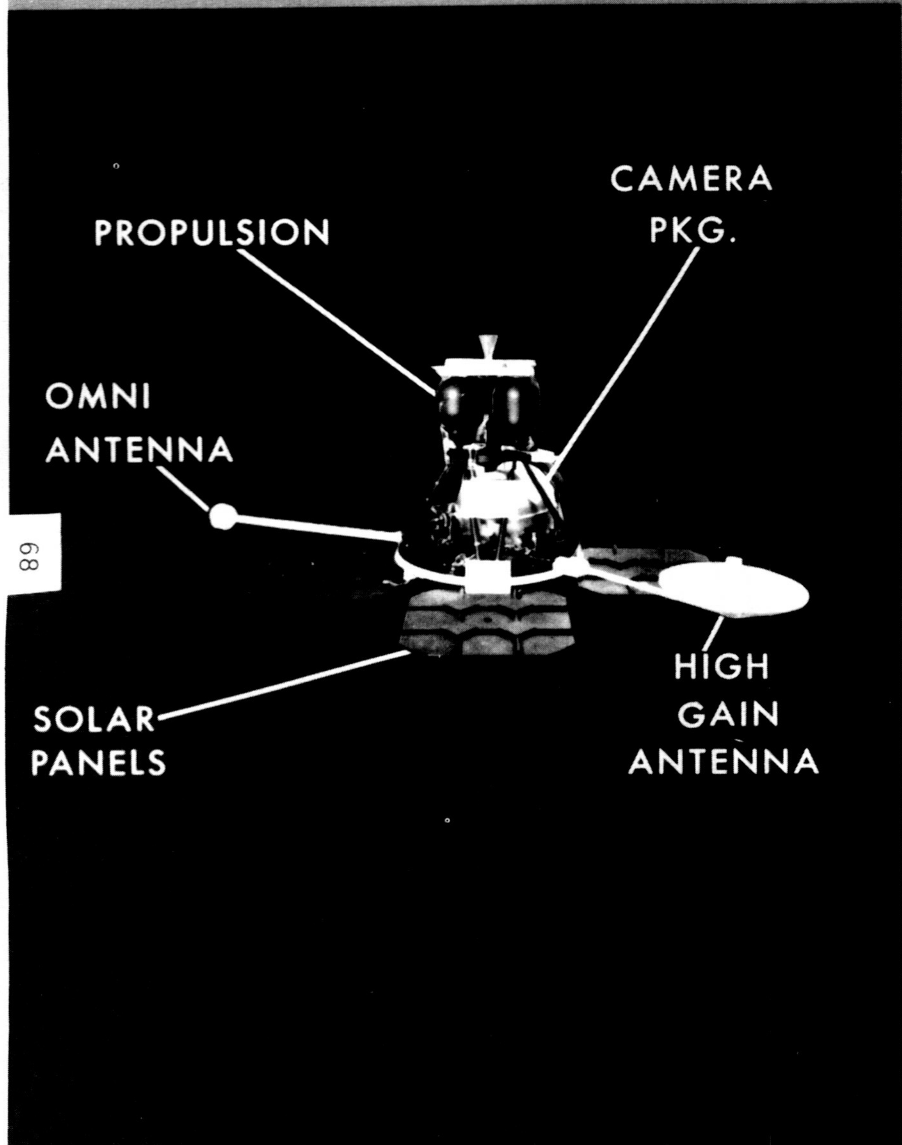
7. Cosmic Ray Ionization - measures flux and ionization rate of galactic cosmic rays.

H. V. Neher	(CIT)
H. R. Anderson	(JPL)

8. Cosmic Dust - measures flux, direction, mass and velocity distribution of micrometeorites in interplanetary space and in the vicinity of Mars.

W. M. Alexander	(GSFC)
O. E. Berg	(GSFC)
C. W. McCracken	(GSFC)
L. Secretan	(GSFC)
J. L. Bohn	(Temple)
O. Fuchs	(Temple)

LUNAR ORBITER



GROSS WEIGHT	830 LBS
INSTRUMENT WEIGHT	130 LBS
INVESTIGATIONS	TELEMETERED FILM PHOTOGRAPHY SELENODESY ENVIRONMENTAL MEASUREMENTS
POWER	235 WATTS (MAX)
STABILIZATION	3 AXIS
DESIGN LIFE	6 MONTHS TO 1 Y 1 MONTH PHOTO
LAUNCH VEHICLE	ATLAS-AGENA
TRAJECTORY	ECCENTRIC LUNA ORBIT
STATUS	DESIGN PHASE

NASA SL64-201
REV 11/16/64

LUNAR ORBITER

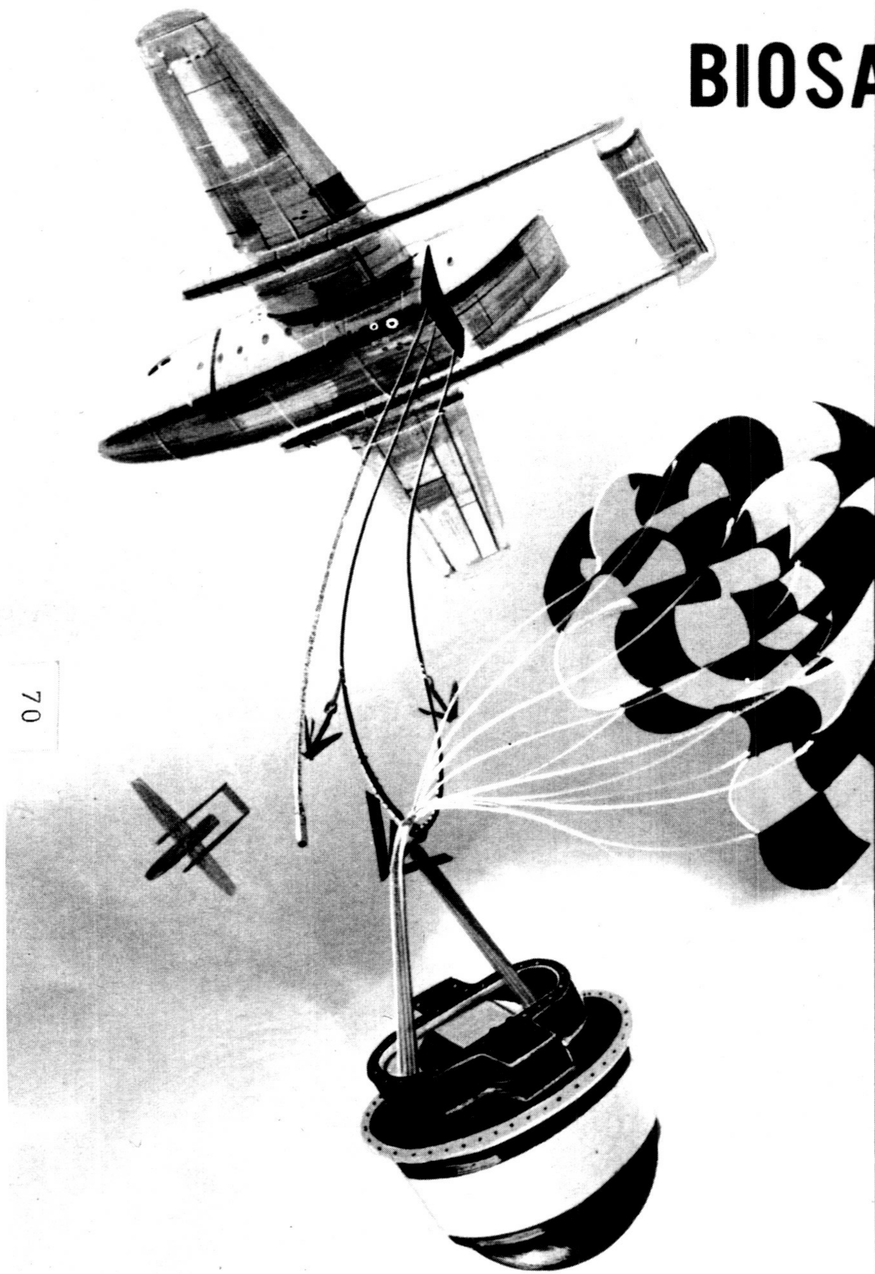
Lunar Orbiter is the NASA program concerned with the investigation of the lunar surface and environment by unmanned spacecraft in eccentric lunar orbits. An approved series of five spacecraft will be launched, beginning in 1966. At present, the detailed design of the spacecraft is in progress.

The primary objective of the program is the photographic reconnaissance of selected areas of the lunar surface to permit the detection and location of small-scale topographic features (such as protuberances 1/2 meter in height). The photographic payload is an integral part of the spacecraft. It exposes and processes film, and then reads out the images for transmission to earth.

Secondary objectives are measurements of the gravity field, shape and mass distribution of the moon (by means of long-term tracking of the orbiting satellite) and monitoring of the micrometeoroid and radiation environments in the vicinity of the moon to obtain data for failure mode analysis as well as to assess potential hazards to later orbiting spacecraft including Apollo. It has been proposed that the selenodesy experiment be a joint effort by Langley Research Center (LRC) and Jet Propulsion Laboratory. LRC will be responsible for the conduct of the micrometeoroid and radiation measurements.

The Lunar Orbiter, together with Surveyor, will assist the Apollo programs by providing lunar topographic information for the selection of landing sites.

BIOSATELITE



GROSS WEIGHT
IN ORBIT 1175 LBS.
RECOVERED CAPSULE 250 LBS.

INVESTIGATIONS
WEIGHTLESSNESS, RADIATION,
AND BIORHYTHMS

POWER FUEL CELLS

TIME IN ORBIT
3 TO 30 DAYS

RECOVERY
AIR SNATCH OR WATER

LAUNCH VEHICLE DELTA

ORBIT
CIRCULAR 230 MI.
INCLINATION 33.5°

PLAN
SIX FLIGHTS, FIRST
FLIGHT EARLY 1966

NASA SB64-214
REV. 11/16/64

BIOLOGICAL SATELLITES

The Biosatellite program is designed to study the unique environmental factors of space, which are the biological effects of zero gravity or weightlessness, and the effects on biological rhythms of removal of living organisms from the earth's rotation. The effects of weightlessness combined with a known source of radiation will be studied to determine if there is any antagonism, synergism, or no effect. It will then be possible to extrapolate to space conditions from the enormous amount of ground based data on biological effects of radiation.

The Biosatellite investigations include studies at the cellular, tissue, organ, and organism levels and include studies on fundamental phenomena such as biochemical reactions, protoplasmic streaming, fertilization, embryological development, and growth investigations at the tissue level. The investigations involving organisms would include physiological (including fluid transport), behavioral, reproductive, genetic and over-all performance studies. They will include investigations with a wide variety of plants and animals from single cellular organisms to higher plants and animals including primates.

Following the announcement of the Biosatellite missions, over 180 proposals for investigations had been submitted by scientists from universities, government, and industry. Panels of scientists reviewed these proposals and 19 are presently selected for flight. The Ames Research Center is cooperating with investigators to determine the engineering, life support, and telemetry requirements. The Ames Research Center has contracted for the development through a prototype stage of the experiment packaging and instrumentation.

The investigations are divided into six categories, including (1) primates, (2) mammalian (non-primate), (3) animal, cellular, and egg, (4) plant morphogenesis, photosynthesis and growth, (5) biorhythm, and (6) radiation experiments. The primate investigations include cardiovascular studies, neurological studies with deep brain probes, skeletal calcium loss, effects of weightlessness on urinary and gastro-intestinal systems, and performance. Pigtail monkeys will be used.

Investigations on the effects of decreased gravity mainly involve cells and higher organisms which have known gravity sensing mechanisms, growth responses, polarization, behavior, or other responses to gravity. In reviewing the large number of proposed investigations the primary consideration was whether there was a valid scientific investigation involved and with some specific hypothesis to be tested.

The radiation investigations will be exposed to weightlessness and a known source of radiation. Strontium 85 will be used in a sintered tungsten-nickel-copper composition sphere. The source can be rotated to the surface to provide from 5000 to 100 RADS in 3 days' orbit. Non-irradiated control investigations will also be flown in the same spacecraft, and a complete duplicate of the radiation investigation will be run on the ground.

Biorhythm investigations will be carried out to help determine whether various circadian and other rhythms are indigenous in the organism or whether they are externally caused by certain environmental factors connected with the earth's period of rotation. The Biosatellite will remove the organism from any day-night, magnetic, or gravitational cyclic influence. The biorhythm specialists are also interested in putting investigations on interplanetary probes to assure complete removal from any fields surrounding the earth which might have any causal effects.

The spacecraft contract was awarded to the General Electric Company.

The Biosatellite Project consists of six (6) flights in space to determine the biological effects on plants and animals of weightlessness, radiation, and the absence of a diurnal cycle. The first flight is planned for the first quarter in 1966 and subsequent flights are scheduled at 3-month intervals. Flights will be of 3, 21, and 30 days' duration.

The satellite will be boosted into an approximate 200 nautical mile circular orbit inclined at about $28\frac{1}{2}$ to $33\frac{1}{2}^{\circ}$ to the equator by a thrust-augmented (improved) Thor-Delta vehicle. The spacecraft will weigh from 1000 to 1200 pounds, and will have a payload capacity of about 6 cubic feet and 150 pounds. All satellites will be recoverable.

The re-entry vehicle and an adapter comprise the spacecraft. The re-entry vehicle is a scaled-up Discoverer satellite in the shape of a truncated cone with a maximum diameter of 40 inches and a length of about 33 inches. The experiments are contained in the re-entry vehicle along with the heat shield and recovery system (parachute and recovery aids) while the adapter contains all of the equipment not necessary for de-orbit re-entry and recovery. The adapter is a conical and cylindrical section from 40 inches to 57 inches in diameter and about 44 inches long.

The 3-day flight, Biosatellitc A, consists of general biology experiments to determine effects on living organisms of the combination of radiation, weightlessness, and the absence of the earth's rotation. The experiments include pepper and flowering plants, wheat seedlings, frog and sea urchin eggs, yeast, wasps, fruit flies, bacteria, amoeba, and embryonic beetles. Fourteen (14) experiments have been selected, three of which have been combined into one package.

The 21-day flight, Biosatellite C, consists of general biology experiments to determine the effects of weightlessness on plant morphogenesis, isolated human cells, gross body composition and function in mammals (rats), and circadian rhythms (biological clocks). Three experiments have been selected for flight.

The 30-day flight, Biosatellite D, consists of primate experiments to determine the effects of weightlessness on behavior and performance, the cardiovascular system, the nervous system (alertness, sleep-wakefulness, fatigue), and general metabolism. Two (2) experiments have been selected for this flight, one of which deals with the primate in flight whereas the other is concerned with pre-and post-flight studies of calcium mobilization and loss from bone.

Investigations and Investigators

Biosatellites A & B (3-day flight)

1. Drs. S. W. Gray and B. F. Edwards (combined with P-1096 and P-1138)
   Emory University
   Atlanta, Georgia

   Experiment P-1020 -- Determination of the effect of weightlessness on the growth and orientation of roots and shoots of wheat seedlings.

2. Dr. Charles J. Lyon (combined with P-1020 and P-1138)
   Dartmouth College
   Hanover, New Hampshire

   Experiment P-1096 -- Determination of the effects of zero gravity on the emergence of seedlings.

3. Drs. H. M. Conrad and S. P. Johnson (combined with P-1020 and P-1096)
   Space and Information Systems Division
   North American Aviation, Inc.
   12214 Lakewood Boulevard
   Downey, California

   Experiment P-1138 -- The effects of weightlessness on the orientation of roots and shoots of seeds.

4. Dr. Richard Young
   Ames Research Center
   Moffett Field, California

   Experiment P-1047 -- Effects on cell fertilization and development in a gravity-dependent system, the frog egg.

5. Dr. Richard Young
   Ames Research Center
   Moffett Field, California

   Experiment P-1048 -- Effects on cell fertilization and development in a gravity-independent cell, the sea urchin egg.

6. Drs. J. C. Finn and S. P. Johnson
   North American Aviation Space and Information Division
   Torrence, California

   Experiment P-1017 -- Effects of weightlessness on plant growth through measurements of the angle between leaf and stem of a pepper plant which is controlled by the plant hormone, auxin.

7. Dr. J. V. Slater
   University of California
   Berkeley, California

   Experiment P-1039 -- Examine the effects of radiation and zero gravity on embryonic differentiation and development of the pupae of Tribolium (flour beetle).

8. Dr. I. I. Oster
   Institute for Cancer Research
   Philadelphia, Pennsylvania

   Experiment P-1160 -- Larvae of Drosophila (fruit fly) which have newly hatched from eggs will be studied to learn of the effects of radiation and zero gravity on the rapidly growing cells of the larvae as they hatch into adults following recovery.

9. Drs. E. Altenberg and L. Browning
   Texas Medical Center, Inc.
   Houston, Texas

   Experiment P-1159 -- Effects of zero gravity on radiation induced damage (mutation and chromosome breaking) in mature reproductive cells of a known genetic strain of female Drosophila previously mated with known genetic males.

10. Drs. A. H. Sparrow and L. A. Schairer
    Brookhaven National Laboratory
    Upton, New York

    Experiment P-1123 -- Determination of the influence of zero gravity on mutation processes in budded stalks of Tradescantia (blue-flowering plant) by observing induced color changes.

11. Dr. R. C. Von Borstel
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Experiment P-1079 -- Male Habrobracon (parasite wasps) will be exposed to several levels of radiation during zero gravity. Post-flight, they will be mated to evaluate the extent of genetic changes.

12. Dr. F. J. DeSerres
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Experiment P-1037 -- Chromosomal mutations in Neurospora (bread mold) following exposure to a known gamma source during zero gravity.

13. Dr. R. H. T. Mattoni
North American Aviation
Downey, California
and
Drs. W. T. Romig and W. T. Ebersold
University of California
Los Angeles, California

Experiment P-1135 -- Slowly growing lysogenic bacteria (*E. coli*) will be exposed simultaneously to zero gravity and radiation to determine whether or not viruses can proliferate within irradiated bacteria under zero gravity.

14. Drs. R. W. Price and D. E. Ekberg
General Electric Company
Philadelphia, Pennsylvania

Experiment P-1035 -- Study in the amoeba (*Pelomyxa carolinensis*) the effects of zero gravity on the orderly synchronous division of nuclei and on the formation of food vacuoles and utilization of ingested nutrients.

Biosatellites C & F (21-day flight)

1. Dr. A. H. Brown
University of Pennsylvania
Philadelphia, Penna.
and
Dr. Orville Dahl
University of Minnesota
Minneapolis, Minnesota

Experiment P-1003 -- Study of plant morphogenesis under weightlessness in a small terrestrial angiosperm (Arabidopsis) to determine whether growth differs qualitatively and quantitatively from plants grown in earth gravitational field.

2. Dr. G. C. Pitts
   University of Virginia
   Charlottesville, Virginia

   Experiment P-1145 -- Effect of weightlessness on gross body composition and metabolism with special reference to atrophy of skeletal muscle and bone, which result from disuse, and to determine patterns of energy expenditure.

3. Dr. P. O'B. Montgomery
   University of Texas
   Southwestern Medical School
   Dallas, Texas

   Experiment P-1084 -- Determination of zero gravity influences on isolated human cells to observe capacity of cell to maintain its membrane to undergo normal mitotic cycles, and to perform normal biochemical and physiologic functions.

Biosatellites D & E

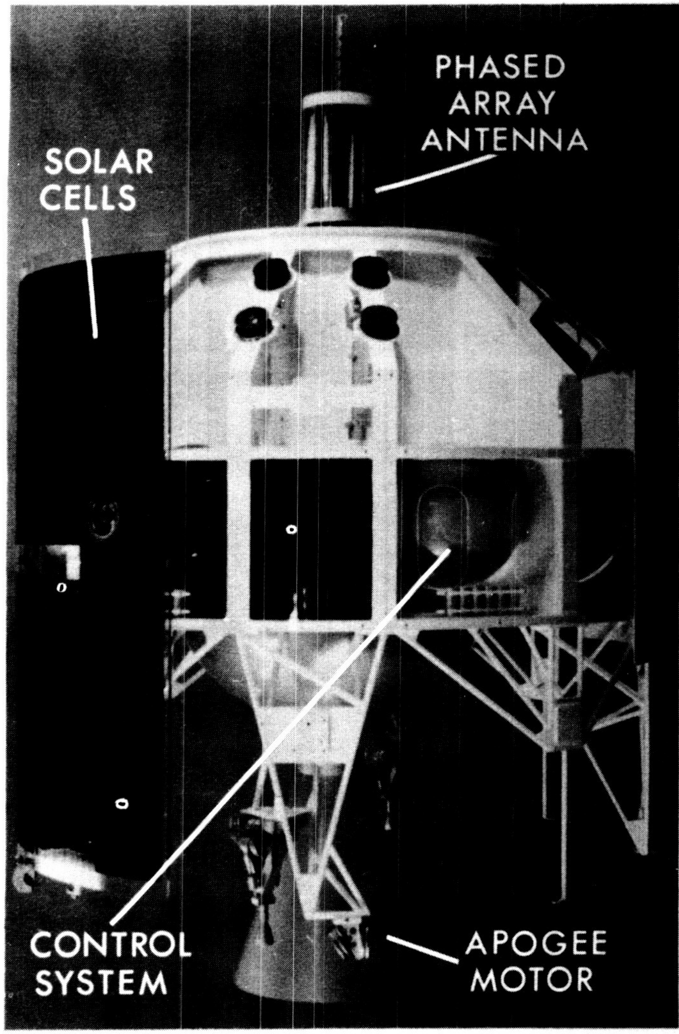
1. Dr. W. R. Adey
   University of California
   Los Angeles, California
   and
   Dr. P. J. Meehan
   University of Southern California
   Pasadena, California

   Experiment P-1001 -- Monitoring of brain functions and performance and cardiovascular and metabolic activities in the primate under prolonged (30 days) weightlessness.

2. Dr. P. B. Mack
   Texas Woman's University
   Denton, Texas

   Experiment P-1062 -- Investigation of losses of bone mineral (calcium) in primates due to immobilization during prolonged weightlessness through radiographic bone densitometry and intensive biochemical analyses pre-and post-flight as well as analyses of excreta collected during flight.

APPLICATIONS TECHNOLOGY SATELLITE



WEIGHT 1500 LBS.
DIAMETER 60 INCHES
ORBIT 6500 MILES AND SYNCHRONOUS

STATUS

STUDYING OTHER USES AND ADAPTABILITY TO GRAVITY GRADIENT EARTH ORIENTATION

DEVELOPING
- APOGEE MOTOR
- PHASED ARRAY ANTENNA
- REACTION CONTROL SYSTEM
- TRANSPONDER
- SINGLE SIDEBAND GROUND EQUIPMENT
- DESIGN FOR EXPERIMENT INTEGRATION

NASA ST64-229
REV. 11/16/64

APPLICATIONS TECHNOLOGY SATELLITES

The Applications Technology Satellites (ATS) are a series of spacecraft intended to serve as a testbed for the development of technology at the 24-hour orbit at certain technical salients critical to further applications, including communications and meteorological satellites. Chief among these is gravity gradient stabilization.

Five flights of three basically different missions are now approved, all using variations of the same basic spacecraft:

a. The first phase spacecraft, to be launched as ATS-A in 1966 with a back-up if necessary in 1967, is designed to provide a very detailed technological gravity gradient experiment. A 710-pound spacecraft will be injected directly into a 6500 mile circular orbit using an Atlas-Agena launch vehicle.

Its fundamental, but not sole, purpose is to provide a basic understanding of the theory necessary to the design of future gravity gradient stabilization systems.

ATS-A will carry television cameras to measure the deflection of the gravity gradient booms with solar heating. Its propellant system will allow adjustment of the eccentricity of the orbit and perturbation of the satellite's orientation in order to measure the restoring period. The angle between the booms will likewise be variable, in order to measure the effect of a change in moment of inertia; and different damping mechanisms will be tested. It is intended to develop sufficient data to permit extrapolation, with confidence, of its results to both higher and lower altitudes.

In addition to its primary gravity gradient experiment, ATS-A will carry the following experiments:

(1) A wideband communications transponder which will also serve the purpose of transmitting to ground stations the output of the meteorological TV camera and the gravity gradient boom TV camera. Receive frequency will be about 6200 Mc, and transmit frequency will be about 4200 Mc.

(2) A meteorological experiment consisting of two television cameras and an associated tape recorder.

(3) An albedo experiment supplied by the Department of Defense.

(4) A radiation damage experiment to measure the damage caused by high energy particles to several types of solar cells with various types and thicknesses of shielding. Principal investigator is Dr. R. C. Waddel of Goddard Space Flight Center (GSFC).

(5) A thermal control coating experiment to measure the absorptivity and emissivity characteristics of several thermal control coatings and to observe how they change in the space environment. Principal investigator is Mr. J. J. Triolo of GSFC.

(6) An experiment to measure the trapped radiation with a multi-element semi-conductor telescope: protons from 0.7 to 100 Mev in six steps, alpha particles from 1.8 to 85 Mev in the five steps, and electrons between 0.5 and 1 Mev and above 1 Mev. Principal investigator is Dr. W. L. Brown and co-investigator is Dr. C. S. Roberts, both of the Bell Telephone Laboratories.

(7) An experiment to measure electromagnetic waves propagating in the whistler mode between 5 kc and 45 kc in eight frequency bands. Principal investigator is Dr. C. S. Roberts of the Bell Telephone Laboratories.

(8) An experiment to measure omnidirectional trapped particles using scintillation detectors; protons with energies greater than 12 and 20 Mev and electrons with energies greater than 0.5 and 1.0 Mev. Principal investigator is Professor C. E. McIllwain and co-investigator is Professor J. Valeris, both of the University of California at San Diego.

(9) An experiment to measure cosmic radio noise over the frequency range 250 kc to 2.5 Mc using the gravity gradient booms as antennae. Principal investigator is Dr. R. G. Stone, and J. K. Alexander is co-investigator, both of GSFC.

(10) On a weight contingency basis, an experiment to measure energetic electrons in the energy range of 20 kev to 5 Mev. Principal investigator is Professor J. R. Winckler and co-investigator is Professor R. Arnaldy, both of the University of Minnesota.

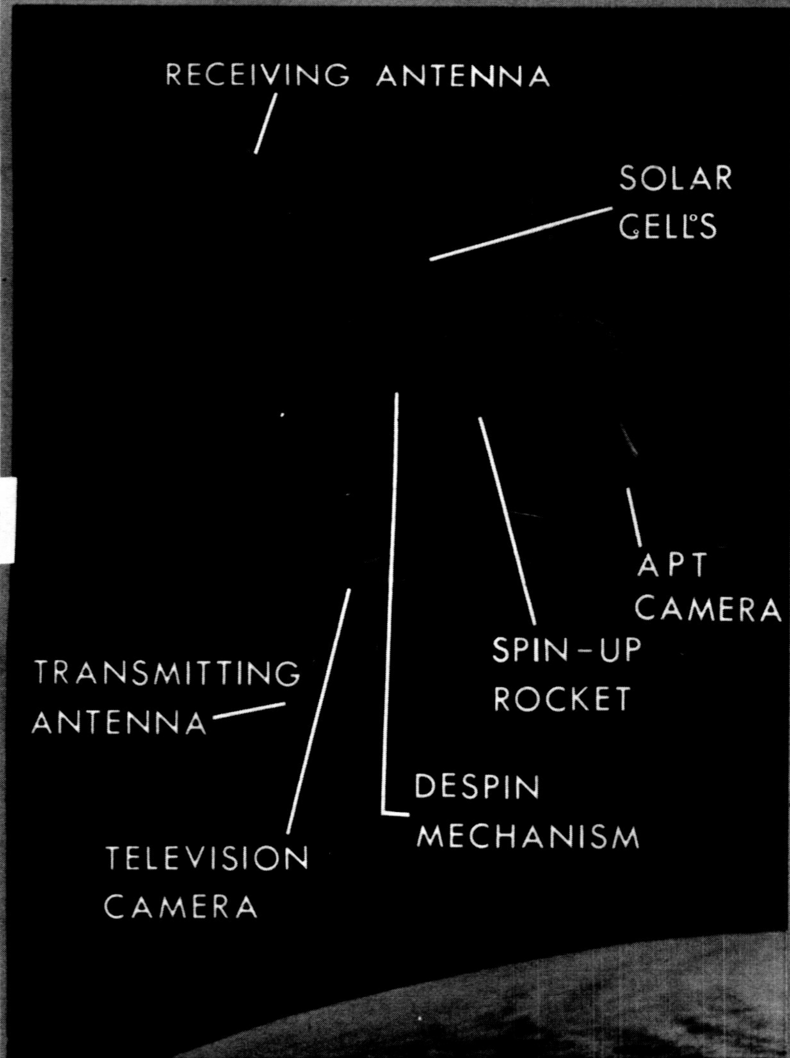
b. The second phase, ATS-B spacecraft will be spin-stabilized and injected into stationary orbit in 1967 using an Atlas Agena plus spacecraft apogee kick motor. This spacecraft and its control equipment are essentially identical to that conceived by the Advanced Syncom study, but carrying only one communications transponder. Although the exact experiment complement has not yet been determined, it is probable that both ATS-B and C will include, in addition to a wideband communications transponder, several of the following kinds of experiments:

Meteorology
Radiation
Navigation
Earth sensor
Multiple access
Electronically and mechanically de-spun antennae

c. Third phase ATS, planned for launch in 1968, would consist of two earth-oriented gravity gradient stabilized spacecraft orbited by Atlas Agena plus spacecraft apogee kick stages.

ATS-D and E will permit NASA to verify its ability to extrapolate gravity gradient data from ATS-A at 6500 miles, to 22,300 miles. It will include further flight tests of promising technology, components, subsystems, and systems for future earth satellite applications.

TIROS VIII



GROSS WEIGHT	265 LBS.
INSTRUMENT WEIGHT	51 LBS.
SENSORS	1 TV CAMERA 1 AUTOMATIC PICTURE TRANSMISSION SYSTEM
POWER	20 WATTS
STABILIZATION	SPIN
DESIGN LIFE	4 MONTHS
LAUNCH VEHICLE	DELTA
ORBIT	APOGEE 470 MI. PERIGEE 440 MI. INCLINATION 58.5°
STATUS	TIROS VIII LAUNCHED 21 DEC ,1963

NASA SF64-220
REV. JAN., 1964

TIROS

The Television Infra-Red Observation Satellites (TIROS) are a series of spin-stabilized spacecraft. Weighing between 260 and 305 pounds, they have been launched into orbit to obtain television and infrared data for use by meteorologists both in research and for operational purposes. Further, these satellites have been used to advance the space technology utilized in meteorological satellites.

The success of the series has led to the extension of the objectives to include developing an improved operational data coverage capability and extending the R&D capability for this type spacecraft.

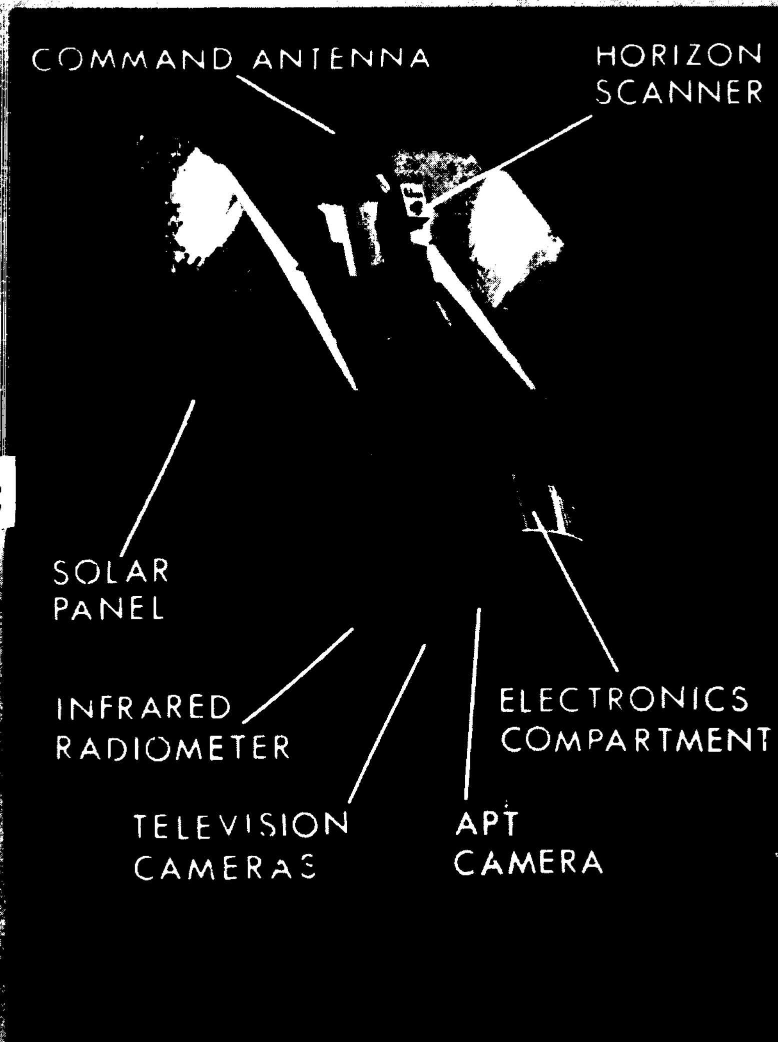
Probably the greatest single contribution of the meteorological satellite program to date is the basis that it has laid for the implementation of the TIROS Operational Satellites (TOS)--an operational system based on TIROS technology. Implementation for TOS is planned for the end of calendar year 1965. In the initial system, two spacecraft types will be used. One will include APT to provide direct local readout of cloud cover data and the second, including AVCS, will provide global cloud cover to be read out at Command and Data Acquisition stations. It is significant to note that both these camera systems were developed for and flown on Nimbus. The basic spacecraft to be used in the operational system is based on the wheel configuration of TIROS.

It is this wheel configuration which will be the next launch in the TIROS series. In this mode of operation, the spin axis is turned so as to be perpendicular to the orbital plane. Thus as it operates, the TIROS wheel in a near polar orbit will sweep out a pole-to-pole swath, taking a picture, as required when the cameras look directly down at the earth. Thus, earth-oriented pictures will be provided continually for the first time from a TIROS satellite. This is the mode of operation of the entire TOS series and all but the first of the developmental OTS series to be flown. It is for this type of use that the wheel configuration is being developed. This first wheel will incorporate two TIROS cameras with their half-inch vidicons which will be canted to the left and right of the orbital path at an angle of 26 degrees so as to provide full coverage. This TIROS I (eye) will be launched early in 1965 into a near-polar, sun-synchronous circular orbit at an altitude of approximately 400 n.m.

Plans include following TIROS I (eye) in the R&D series with TIROS K in an eccentric orbit. This eccentric orbit mission will utilize a spacecraft in the basic axial viewing TIROS configuration. That is, it will not be a wheel. The spacecraft would be launched into a highly elliptical orbit with an apogee near 20,000 n.m. and a perigee at approximately 180 n.m. Included will be a low resolution camera and a high resolution camera with resolutions of 8.7 and 1.3 n.m. per TV line and an infrared sensor for radiometric measurements. These sensors will be used to view the entire disc of the earth as well as for continuous observation of a particular cloud area.

Orbiting with its spin axis always pointing in the same direction in space, TIROS would provide two to three hours of data which would cover both the full disc of the earth and a particular field of view during each orbit. Due to the shape of the projection of the orbit on the surface of the earth, the observations are made prior to, and at apogee rather than on both sides of the apogee. The data recorded during the viewing time will allow the meteorologist to follow continuously individual weather patterns for several hours for the first time. It is believed this will provide highly interesting and valuable data for the research meteorologist.

NIMBUS C



GROSS WEIGHT	900 LBS.
INSTRUMENT WT	198 LBS.
EXPERIMENTS	4
POWER	450 WATTS
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	SIX MONTHS TO ONE YEAR
LAUNCH VEHICLE	TAT-AGENA B
ORBIT	CIRCULAR 600 NM INCLINATION 80° RETROGRADE
STATUS	UNDER DEV. FLIGHT IN 1965

NASA SF64-222
REV-11-19-64

NIMBUS

Nimbus is a three-axis, earth-oriented spacecraft capable of providing full earth coverage on a daily basis by means of a near-solar orbit having an inclination of approximately 80 degrees to the equator. The exact orbits are so chosen so that the satellite crosses the plane of the equator at the same times (e.g., noon and midnight) each orbit.

The Nimbus concept calls for development of a spacecraft suited to the above orientation and orbit with space and power available to carry a variety of experiments for atmospheric research and operational application.

In this work the satellite is considered a meteorological observatory in space. As such, the spacecraft must constitute a platform for sensor testing, a platform for subsystem testing, a platform where special atmospheric observations can be made (for example, sferics observations or observations of the atmospheric ozone) and, finally, a platform from which simultaneous measurements can be made. These measurements would be of the many atmospheric parameters which are essential to the full description of the atmosphere and the understanding of it. It is also useful to take measurements simultaneously of space environmental factors (the solar environment) and the co-existing behavior of the earth's atmosphere, thus permitting a time correlation of the two.

Nimbus C

The Nimbus C spacecraft was originally the backup spacecraft for Nimbus I, which was launched on August 28, 1964, and ceased providing useful data on September 23, 1964. Therefore, the instrumentation under consideration for Nimbus C is an augmented version of Nimbus I. That is, the instrumentation for Nimbus C will include the Advanced Vidicon Camera System (AVCS), the Automatic Picture Transmission (APT) subsystem, and the High Resolution Infrared Radiometer (HRIR), all of which were carried aboard Nimbus I, plus the Medium Resolution Infrared Radiometer (MRIR).

The AVCS is a three camera array, each utilizing a one-inch vidicon with an 800 TV line resolution. The system is capable of providing full global daylight cloud cover data.

The APT subsystem automatically snaps a TV picture and by a slow scan technique transmits cloud cover pictures directly to relatively inexpensive ground stations within radio range of the satellite.

The HRIR uses 3.4 to 4.2 micron region of the infrared spectrum to provide nighttime cloud cover data. On Nimbus C the night cloud cover data are also planned to be broadcast to specially equipped APT ground stations, as well as to the conventional CDA stations. A resolution of about 5 miles has been achieved.

The MRIR is a five-channel radiometer that provides data concerning the emitted and reflected radiation of the earth's surface in five spectral bands:

Channel 1, Water vapor absorption band 6.5 to 7.0 microns

Channel 2, Atmospheric window 10 to 11 microns

Channel 3, CO_2 content of the atmosphere 14 to 16 microns

Channel 4, Terrestrial radiation, 5 to 30 microns

Channel 5, Albedo radiation, 0.2 to 4 microns

These data will be obtained with a resolution of about 30 miles.

<u>Nimbus B</u>

A number of candidates are being considered in terms of sensors and subsystems to be carried on Nimbus B and follow-on spacecraft to be included in the program. These candidates will probably not all fit on one spacecraft and might well be included on more than one spacecraft. As candidates, these are listed according to function, without reference to priority.

1. Provide direct measurement of the atmospheric structure:
   Infrared Interferometer/Spectrometer
   MRIR
   Oxygen Band Microwave Radiometer

2. Provide data collection capability:
   Interrogation, recording, and location subsystem
   Weather Data Relay via APT

3. Extend meteorological observations to regions of the terrestrial and solar spectrum not previously covered:
   Solar Ultraviolet investigation
   Sferics investigation
   Back-scatter ultraviolet

4. Support meteorological observations and sensor technology advancements:
   AVCS - with wide angle lenses
   HRIR - with direct readout via APT
   APT - direct readout and recording capabilities.

MANNED SPACE SCIENCE

Within the Office of Space Science and Applications (OSSA) the Manned Space Science Office (MSS) is functionally responsible to both the OSSA and the Office of Manned Space Flight (OMSF) as the coordinating point for scientific support of OMSF projects.

Apollo Project Science Program

For the Apollo Project Science Program, possible investigations in the fields of geology, geophysics, bioscience, and atmospheric studies are being considered. Mission profiles for the astronaut on the lunar surface are now being simulated. Design criteria and requirements for a Lunar Sample Receiving Laboratory are being prepared. An opportunity for submitting proposals for manned lunar exploration was announced in June 1964 in the OSSA booklet "Opportunities for Participation in Space Flight Investigations."

Inflight Sciences Program

The experiments chosen for Gemini have evolved from the few Mercury scientific experiments and will be among the first attempts to utilize the presence of man on board a spacecraft to carry out scientific tasks. The list of approved experiments is given below.

Experiments for early Apollo Earth-orbital flights on Saturn IB are under review. Because of greater weight, space and power available, and the longer duration of these flights, it is expected that these experiments will be more sophisticated than those for Mercury or Gemini.

Scientist-Astronaut Program

The ultimate role of man in space as an investigator will be realized in the selection of scientifically-trained astronauts in a joint NAS-NASA effort.

Investigations and Investigators

Gemini Flights

1. Sea Urchin Egg Growth Under Zero-G - Flight 3.

   R. S. Young
   Ames Research Center

2. Synergistic Effect of Zero-G and Radiation on White Blood Cells - Flight 3.

   M. A. Bender
   Atomic Energy Commission

3. Synoptic Terrain Photography - Flights 4, 5, 6, 7.

   P. D. Lowman
   Goddard Space Flight Center

4. Synoptic Weather Photography - Flights 4, 5, 6, 7.

   K. Nagler
   U.S. Weather Bureau

5. Visual Acuity in the Space Environment - Flights 5, 7.

   S. Q. Duntley
   Scripps Institute of Oceanography

6. Spectrophotograph of Clouds - Flights 5, 8.

   F. Saiedy
   U.S. Weather Bureau

7. Zodiacal Light and Airglow Photography - Flights 5, 8, 9, 10.

   E. P. Ney, W. Huch
   Institute of Physics, University of Minnesota

8. Airglow Horizon Photography - Flights 5, 9, 11.

   M. J. Koomen, D. M. Packer, R. Tousey
   Naval Research Laboratory

9. Frog Egg Growth Under Zero-G - Flight 8.

   R. S. Young
   Ames Research Center

10. Nuclear Emulsion - Flight 8.

    M. M. Shapiro
    Naval Research Laboratory

    C. E. Fichtel
    Goddard Space Flight Center

11. Collecting of Micrometeorites - Flight 9.

C. L. Hemenway
Dudley Observatory

12. UV Photography of Celestial Sources - Flights 10, 11.

K. G. Henize
Northwestern University

SUMMARY OF NASA LAUNCH VEHICLES

Introduction

The following summarizes the capabilities of NASA launching vehicles for space research and exploration. The vehicles fall into two general categories:

1. Sounding rockets

2. Satellite and space probe vehicles

The sounding rockets are relatively inexpensive and simple to operate but are limited to small payloads and vertical-or-near-vertical flights. The satellite and space probe vehicles are ranged from the Scout all-solid launch vehicle to very large vehicles capable of launching man-carrying spacecraft on missions to the lunar surface and return.

Sounding Rockets

Description: A family of six sounding rockets is used in the geophysical sounding program. These are relatively simple rockets that can be launched at precise times from several sites. About 90 are being launched each year from Wallops Island, Fort Churchill, White Sands, and foreign sites.

The types of programs in which these rockets are being used show a strong dependency of objectives or requirements of subsequent firings on the findings of the initial firings in a given family of observations. Consequently, specific long-range firing schedules are not practical for sounding rockets. Based on projected research program planning, a sufficient number of each rocket type is ordered to satisfy the various program needs foreseen.

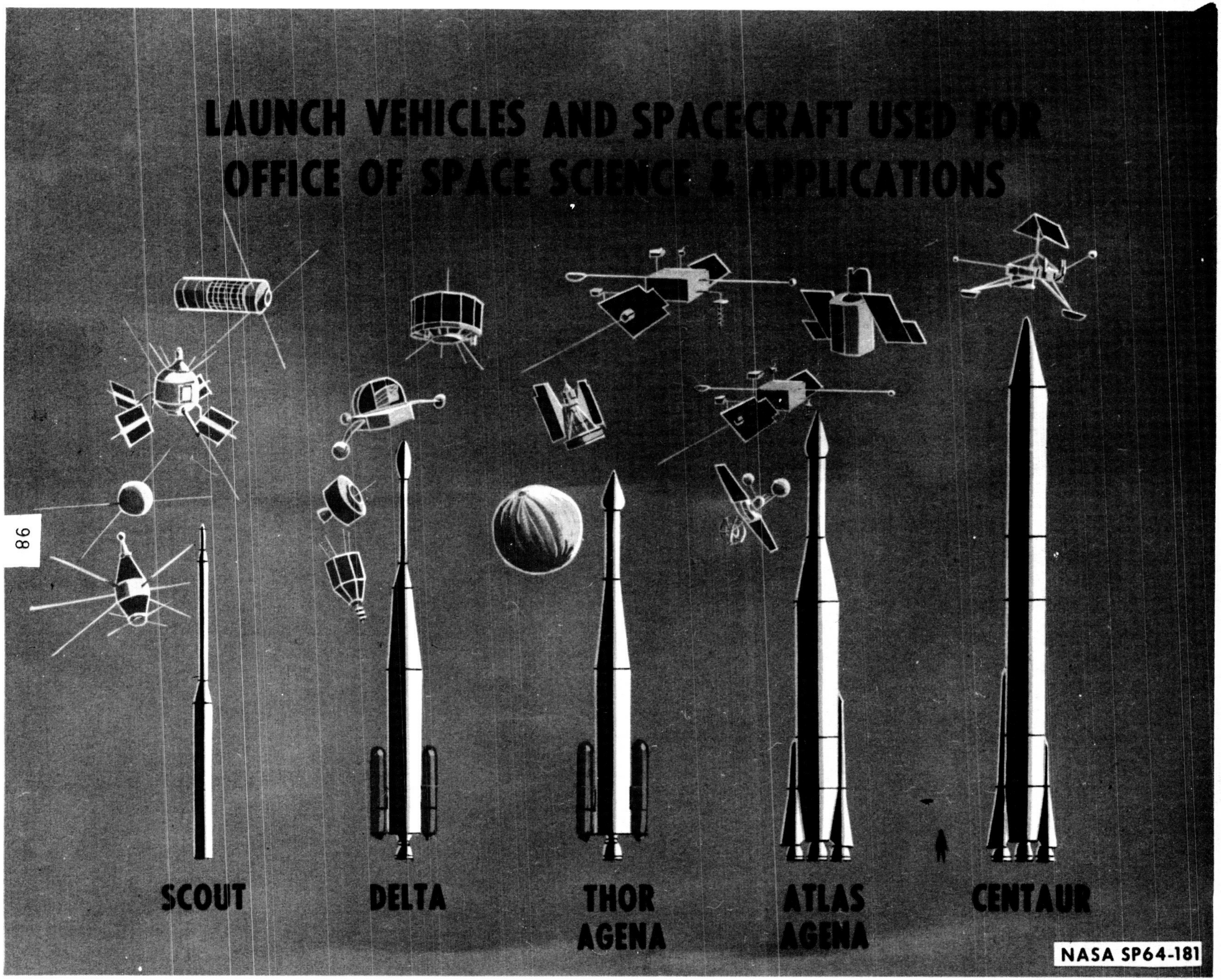
Typical sounding rockets now utilized are listed in the following table with their nominal costs and capabilities:

Vehicle	Cost (Thousands of Dollars)	Capability Altitude (miles)	Capability Payload Wt. (pounds)
Nike-Apache	7.5	150	50
Aerobee 150, 150A	30	150	150
Aerobee 300	38	230	50
Argo D-4	50	625	100
Argo D-8	140	1150	130
Nike-Cajun	6	100	50

It is expected that two additional sounding rockets, now undergoing performance evaluation, will be added to the above available vehicles during calendar year 1965.

They are the following:

Vehicle	Cost (Thousands of Dollars)	Altitude (miles)	Payload Wt. (pounds)
Aerobee 350	not available	290	150
Astrobee 1500	150	1200	130


LAUNCH VEHICLES AND SPACECRAFT USED FOR
OFFICE OF SPACE SCIENCE & APPLICATIONS
SCOUT
DELTA
THOR
AGENA
ATLAS
AGENA
CENTAUR
NASA SP64-181

Satellite and Space Probe Vehicles

The objectives of the Launch Vehicle and Propulsion Programs are to provide vehicles with the capability to perform reliably and economically the unmanned orbital, lunar, planetary, and interplanetary missions. Satellite and space probe vehicles currently available in the program are Scout, Delta, Thor-Agena, Atlas-Agena. Vehicles under development to support future missions are Atlas-Centaur.

The plan for Launch Vehicles to meet unmanned satellite and space probe mission requirements considers the following:

Mission	Spacecraft Weight Range
Orbital	150 to 30,000 lbs.
Lunar	900 to 9,000
Planetary	570 to 7,000

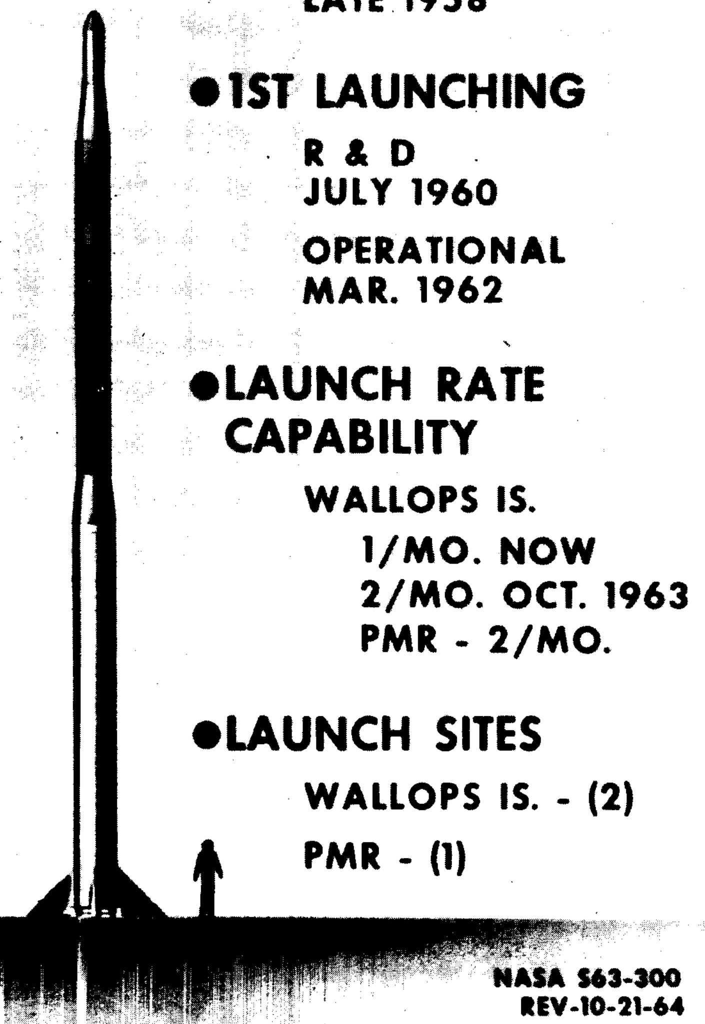
Weight ranges when considered from a Launch Vehicle point of view can be categorized into three groups: Small, medium, and large. The range of payload capability by vehicle class is:

Mission	Small	Medium	Large
	Scout, Delta	Thor-Agena Atlas-Agena Atlas-Centaur	Saturn 1B (2 & 3 stages)
Earth Orbital	150-800 lbs.	2,000 to 10,000 lbs.	30,000 lbs.
Escape	50 lbs.	850 to 2,000 lbs.	8,000 lbs.
Planetary	0	570 to 1,500 lbs.	7,000 lbs.

A description of each launch vehicle, along with its capabilities is provided in the following paragraphs:

SCOUT

- **STAGES**
  - 1ST STAGE - SOLID (ALGOL)
  - 2ND STAGE - SOLID (CASTOR)
  - 3RD STAGE - SOLID (ANTARES)
  - 4TH STAGE - SOLID (ALTAIR)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT 240, 38° INC .
- **USE**
  - ORBIT
  - HIGH ALTITUDE PROBE
  - RE-ENTRY



- **INITIATED**
  - LATE 1958
- **1ST LAUNCHING**
  - R & D
JULY 1960
  - OPERATIONAL
MAR. 1962
- **LAUNCH RATE CAPABILITY**
  - WALLOPS IS.
    - 1/MO. NOW
    - 2/MO. OCT. 1963
    - PMR - 2/MO.
- **LAUNCH SITES**
  - WALLOPS IS. - (2)
  - PMR - (1)

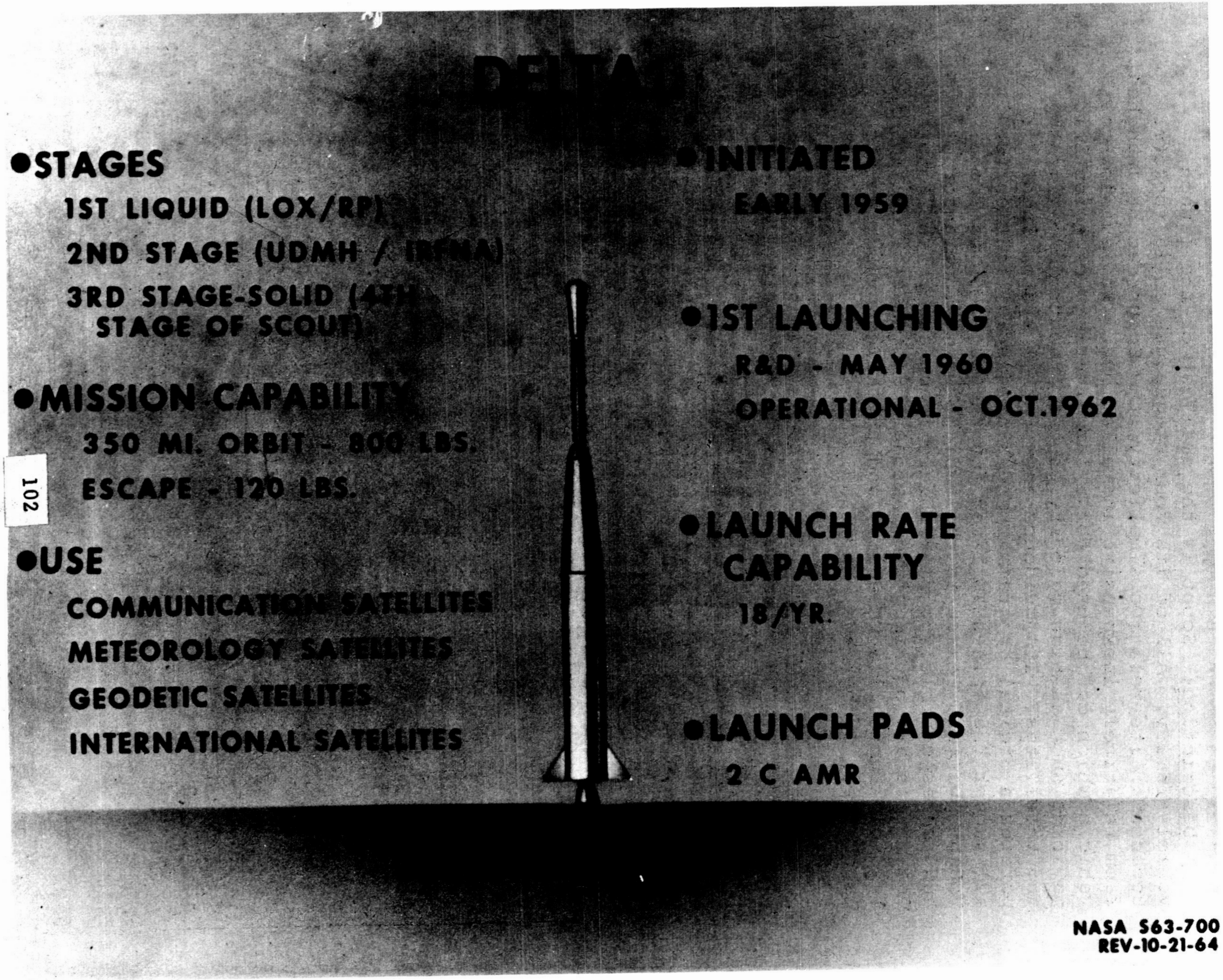
NASA S63-300
REV-10-21-64

SCOUT

Description: Scout is the smallest of the launch vehicle family. All of its four stages use solid rockets. Because of its relative simplicity, the Scout can be launched from relatively inexpensive installations. It is a low-cost vehicle which can be used for a large variety of scientific payloads such as high velocity probes, reentry experiments and satellites. Its guidance and control system incorporates a digital programmer and 3-axis stabilization for all except the spin-stabilized fourth stage. Ling-Temco-Vought, Dallas, Texas, is the vehicle prime contractor and is responsible for all vehicle items except the motors. The motors are obtained from Aerojet, Sacramento, California; Thiokol, Huntsville, Alabama; and the Allegany Ballistics Laboratory, Cumberland, Maryland.

Mission Capability: The present Scout is capable of placing 240 pounds in a 300 n.m. easterly orbit.

Schedule: Starting with the first flight on July 1, 1960, eight developmental and twenty-six operational vehicles have been flown to date. A well integrated Scout program has been established between NASA and DOD. Forty-nine vehicles will have been procured through CY 1964 to fulfill NASA, AEC, and DOD requirements. In addition, a fully integrated logistic support system for the two Scout launch sites (Wallops Island and PMR) has been established by NASA with joint funding.


DELTA
●STAGES
1ST LIQUID (LOX/RP)
2ND STAGE (UDMH / IRFNA)
3RD STAGE-SOLID (4TH STAGE OF SCOUT)
●MISSION CAPABILITY
350 MI. ORBIT - 800 LBS.
ESCAPE - 120 LBS.
●USE
COMMUNICATION SATELLITES
METEOROLOGY SATELLITES
GEODETIC SATELLITES
INTERNATIONAL SATELLITES
●INITIATED
EARLY 1959
●1ST LAUNCHING
R&D - MAY 1960
OPERATIONAL - OCT.1962
●LAUNCH RATE CAPABILITY
18/YR.
●LAUNCH PADS
2 C AMR
NASA S63-700
REV-10-21-64

DELTA

Description: The Delta is a three-stage vehicle, in which the first stage consists of a production Thor space launch booster. The second stage is a modified version of the Vanguard second stage. A radio guidance system (BTL) is installed in the second stage to provide velocity and attitude control. This includes coast-phase attitude control which affords much higher orbits with Delta than with previous vehicles since a prescribed vehicle attitude can be maintained up to 2000 seconds after second-stage burnout. An ABL X-258 solid propellant rocket motor is used as the Delta third stage. Prior to ignition, this stage is spun up to approximately 150 rpm to obtain spin stability after separation, since neither guidance nor autopilot is carried in the third stage.

Mission Capability: The Delta is capable of launching a 120-pound space probe or putting an 800-pound payload into a 350 n.m. circular orbit.

Schedule: The first Delta flight was scheduled for 1960. Delta has been successful in 23 out of 26 launch attempts.

Additional vehicles have been ordered for use with scientific, meteorological and active communication satellite programs. These launches will continue well into calendar year 1967, and perhaps beyond, at a rate of eight to ten per year.

THRUST AUGMENTED DELTA (TAD)

Description: The Thrust Augmented Delta is a three and one half stage vehicle which differs from the Delta in that it utilizes the USAF developed, improved Thor Booster as a first stage. The improved Thor (SLV-2A) employs three (3) THIOKOL XM-33-#2 solid propellant rocket motors mounted around the base of the Thor Booster increasing the lift off thrust from 170,000 lbs. to 330,000 lbs. The solid motors are expended at approximately 40 seconds and are separated from the booster at an appropriate time thereafter. The upper stages are not changed from the standard Delta.

Mission Capability: This vehicle combination is capable of placing 1,000 lbs. into a 300 n.m. circular orbit and of placing 135 lbs. to escape.

Schedule: The Thrust Augmented Delta was first launched successfully on Delta No. 26 which placed SYNCOM-C into synchronous transfer orbit on 17 August 1964.

IMPROVED DELTA

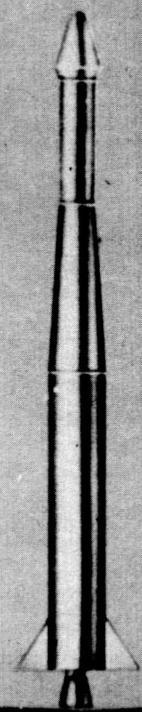
Description: The Improved Delta differs from the current Delta in that the second stage tank diameter will be increased to provide additional propellant capacity (i.e., 54 inch diameter), and the larger diameter Nimbus fairing (i.e., 60 inch diameter) will be adopted for Delta use to provide additional payload volume. The improved second stage will be flown with or without first stage thrust augmentation and the X-258 third stage will be retained.

Mission Capability: The vehicle combination is capable of placing 1200 lbs. into a 300 n.m. circular orbit and of placing 186 lbs. to escape in the thrust augmented configuration.

Schedule: The Improved Delta will become operational in the third quarter of CY 1965.

THOR-AGENA B

- **STAGES**
  - 1ST STAGE - LOX/P-1 (THOR)
  - 2ND STAGE - IRFNA/UDMH (AGENA B)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT 1600 LBS
  - 1200 N. MI. ORBIT 850 LBS
- **USE**
  - METEOROLOGICAL AND SCIENTIFIC SATELLITES



- **INITIATED**
  - EARLY 1959 (DOD)
- **1ST LAUNCHING**
  - LATE 1962 (NASA)
- **LAUNCH SITE**
  - PMR
- **LAUNCH RATE CAPABILITY**
  - 10/YR

NASA S63-701
Rev. 8-1-63

THOR AGENA

Description: The Thor Agena is a two stage rocket consisting of a Thor first stage using liquid oxygen and RP-1 propellants and an Agena second stage using UDMH and IRFNA as the propellants. The vehicle is 8 ft. in diameter and weighs 125,000 pounds. The booster thrust is 170,000 pounds; the Agena second stage thrust level is 16,000 pounds.

Mission Capability: This vehicle is capable of launching a payload of 1600 pounds into a 300 n.m. circular orbit or an 850 pound Nimbus spacecraft into a 500 n.m. circular, polar orbit.

Schedule: Three (3) Thor Agena vehicles are currently scheduled for launch through 1965. All current Thor-Agena launches are for scientific and applications satellites which require polar orbits.

IMPROVED THOR AGENA (TAT)

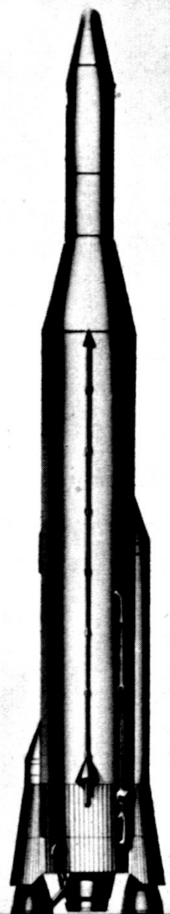
Description: The Improved Thor Agena is a two and one half stage rocket consisting of a Thor booster with three (3) solid rocket engines mounted around the periphery of the Thor base and an Agena D as a second stage. The total lift-off thrust is increased to 350,000 pounds by the addition of the solid rocket engines. The solid rockets burnout by approximately 40 seconds after lift-off and are designed to drop away from the basic Thor vehicle at approximately 60 seconds.

Mission Capability: This vehicle combination is capable of placing an 1100 pound payload into a 750 n.m. circular, polar orbit.

Schedule: An Improved Thor Agena (TAT) vehicle is scheduled to launch an Orbiting Geophysical Observatory from PMR into a polar orbit early in 1965. It is planned to use this vehicle for all Polar Orbiting Geophysical Observatories as well as scientific and weather satellite programs throughout 1965 and 1966.

ATLAS-AGENA B

- **STAGES**
  - 1ST STAGE - LOX/RP-1 (ATLAS)
  - 2ND STAGE - IRFNA/UDMH (AGENA B)
- **MISSION CAPABILITY**
  - 300 N. MI. ORBIT - 6,000 LBS.
  - LUNAR PROBE - 850 LBS.
  - PLANETARY PROBE - 550 LBS
- **USE**
  - LUNAR PROBES
  - COMMUNICATIONS SATELLITES
  - SCIENTIFIC SATELLITES



- **INITIATED**
  - MID 1959 (DOD)
- **1ST LAUNCHING**
  - MID 1961 (NASA)
- **LAUNCH RATE CAPABILITY**
  - 10/YR./PAD
- **LAUNCH SITE**
  - AMR - 1 PAD
  - 2 PADS AVAILABLE FOR BACK-UP

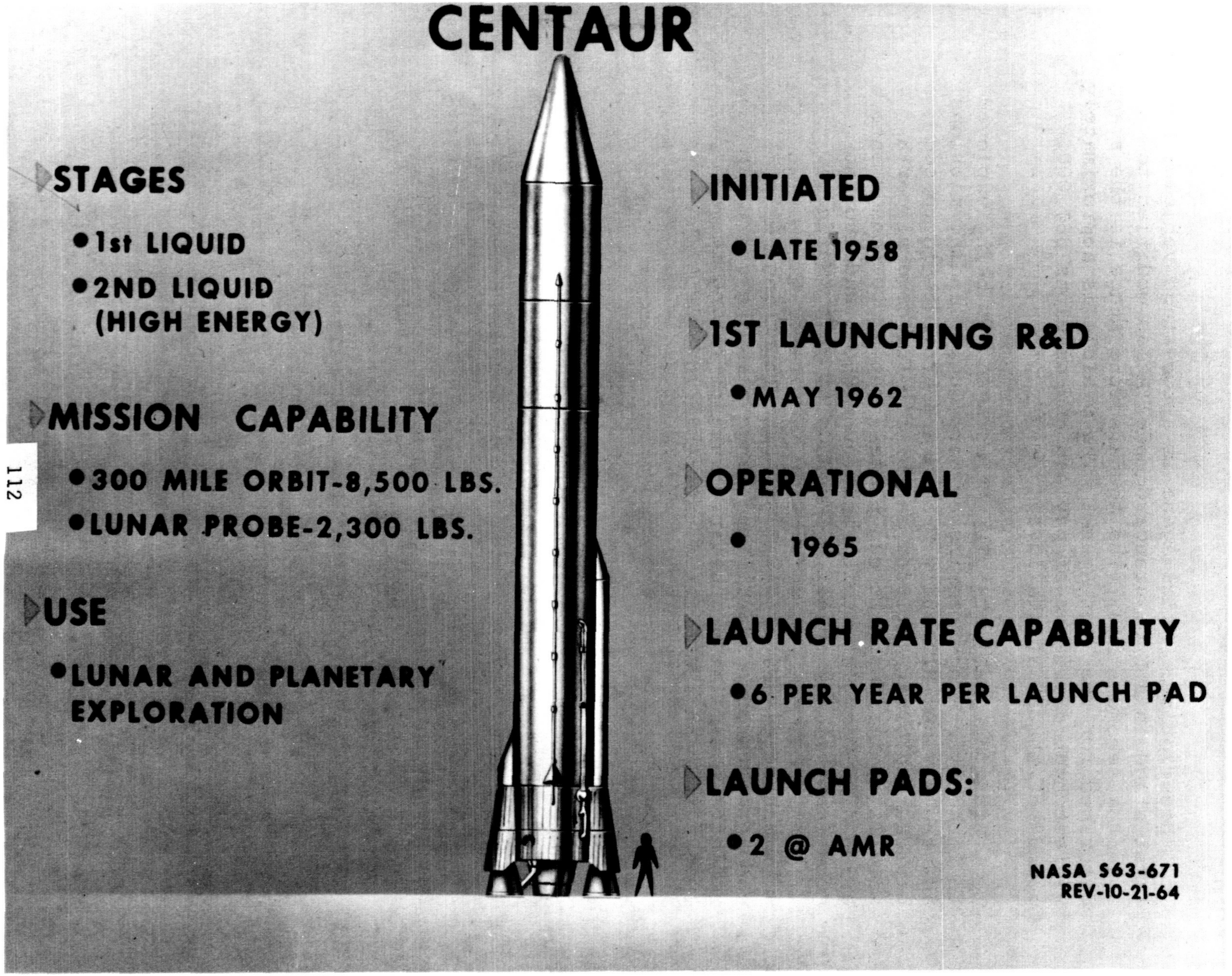
NASA S63-299
REV-10-21-64

ATLAS AGENA

Description: Atlas Agena is a two-stage vehicle. The first stage is a D or standard model Atlas modified to accept a second stage. The Agena second stage is the stage described for the Thor Agena. The vehicle is approximately 91 feet high exclusive of payload and develops 367,000 pounds of thrust at sea level.

Mission Capability: The Atlas Agena is being employed to launch the Ranger series of hard lunar landing missions and the Mariner Planetary Probes and provides increased payload and orbit altitude capability for several earth satellite missions. It can place about 5,000 pounds into a 300 n.m. circular orbit, send over 850 pounds to the moon (Ranger), or inject 570 pounds to Mars (Mariner).

Schedule: Five (5) Atlas Agena Launchings were completed through 1964. Long range planning currently reflects a similarly sustained rate of firing through 1965, 1966 and 1967 with a taper-off in 1968.



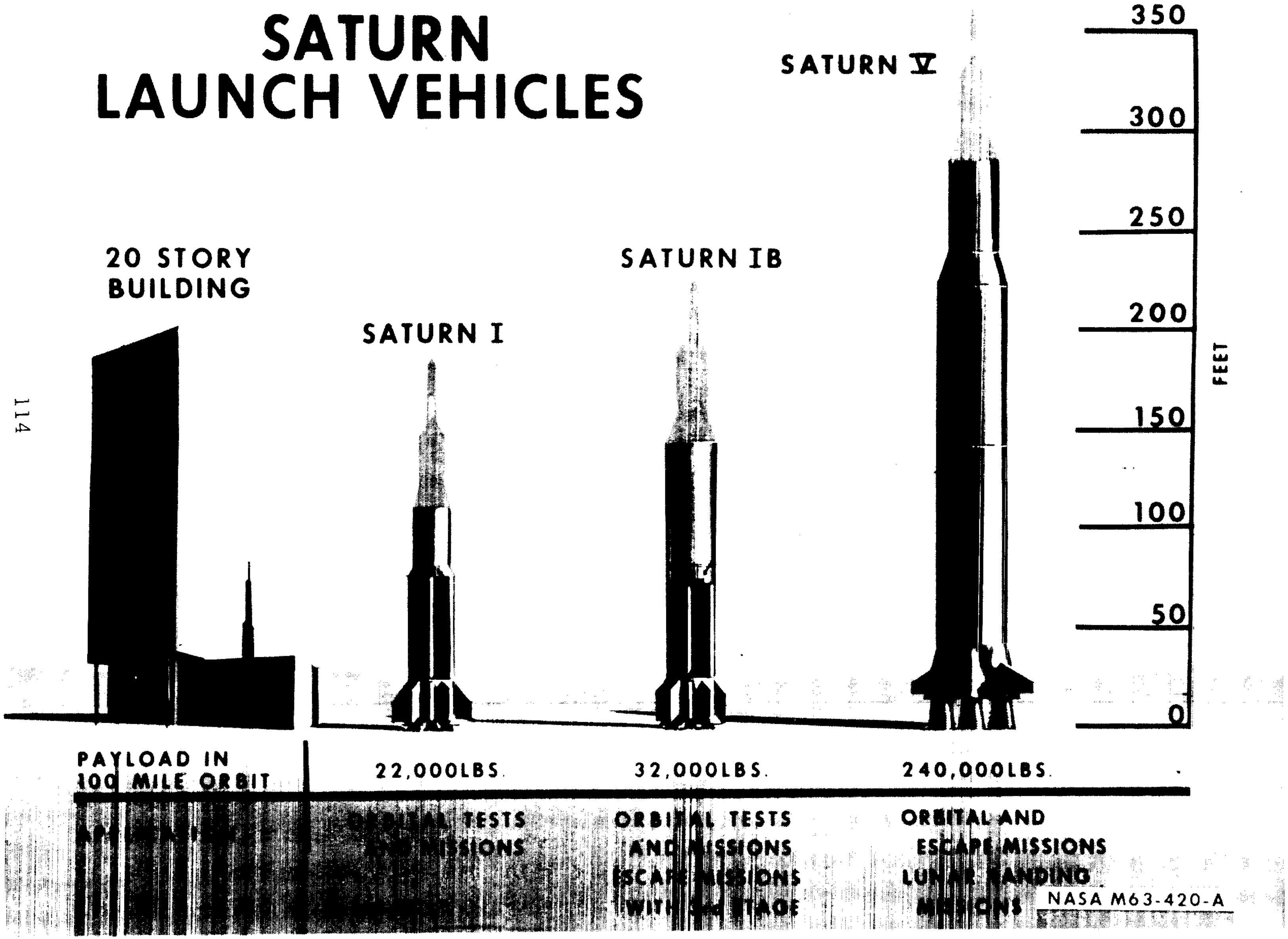
CENTAUR
STAGES
1st LIQUID
2ND LIQUID (HIGH ENERGY)
MISSION CAPABILITY
300 MILE ORBIT-8,500 LBS.
LUNAR PROBE-2,300 LBS.
USE
LUNAR AND PLANETARY EXPLORATION
INITIATED
LATE 1958
1ST LAUNCHING R&D
MAY 1962
OPERATIONAL
1965
LAUNCH RATE CAPABILITY
6 PER YEAR PER LAUNCH PAD
LAUNCH PADS:
2 @ AMR
NASA S63-671
REV-10-21-64

CENTAUR

Description: Centaur is a 10 ft. diameter high-energy upper stage powered by two Pratt and Whitney RL 10-A-3 liquid hydrogen-liquid oxygen engines of 15,000 pound thrust each. Centaur will use a modified Atlas-D as a first stage. This configuration is over 105 feet long and weighs about 300,000 pounds at launch.

Mission Capability: The high energy propellants used in Centaur give it a payload capability substantially above that of the Atlas-Agena B. Atlas-Centaur can place a payload of over 8,500 pounds in a low earth orbit. Its performance advantages for high velocity missions is even more marked. It will be used by NASA principally for the Surveyor series of unmanned soft lunar landings and the Mariner planetary shots.

Schedule: The first development flight of Centaur took place on May 8, 1961. The vehicle failed during first stage flight, probably due to aerodynamic forces. The second and third development flights have been considered successful. The development test program extends to 1965 followed thereafter by the launching of Surveyor payloads. Centaur, as an upper stage for Atlas, is expected to remain operational throughout this decade.


SATURN
LAUNCH VEHICLES
20 STORY
BUILDING
SATURN I
SATURN IB
SATURN V
350
300
250
200
150
100
50
0
FEET
PAYLOAD IN
100 MILE ORBIT
22,000LBS.
32,000LBS.
240,000LBS.
ORBITAL TESTS
AND MISSIONS
ESCAPE MISSIONS
ORBITAL AND
ESCAPE MISSIONS
LUNAR LANDING
MISSIONS
NASA M63-420-A

SATURN 1

Description: The Saturn 1 is a multi-purpose space booster vehicle of approximately 1.6 million pounds of initial thrust. The first stage, approximately 80 feet long, 257 inches diameter, weighing 108,000 pounds dry, is powered by eight Rocketdyne H-1 engines of 200,000 pounds thrust each. The four inner engines are fixed and the four outer engines are gimballed for pitch, yaw, and roll control. Of the nine propellant tanks, the center tank and four of the outer tanks contain liquid oxygen and the remaining four hold the hydrocarbon fuel.

The Saturn S-IV, approximately 41 feet long, 200 inches diameter, weighing 14,000 pounds dry, is powered by six Pratt and Whitney RL10-A-3 engines of approximately 15,000 pounds thrust each (Centaur engines) and will burn approximately 100,000 pounds of liquid oxygen and liquid hydrogen.

Mission Capability: The vehicle will be used for Apollo unmanned orbital test missions, with a payload capability of about 17,000 pounds in a 300 n.m. orbit.

Description: The 1B is a two-stage launch vehicle. The first stage (S-1B) to be powered by a cluster of H-1 engines developing a total sea level thrust of approximately 1,600,000 pounds. The second stage (S-IVB) to be powered by a single J-2 engine developing a total vacuum thrust of approximately 200,000 pounds. The first stage will be a slightly modified version of the current S-1 stage developed by MSFC. The second stage will be a slight modification to the S-IVB stage currently being developed by Douglas for use on the Saturn V based on design concepts from MSFC.

Mission Capability: Primary Mission. The primary mission of the 1B launch vehicle two-stage configuration shall be to place an Apollo spacecraft, weighing approximately 32,000 pounds, without lunar mission propellants, into an earth orbit of approximately 105 nautical miles.

Other Missions. The 1B launch vehicle will provide an early means of demonstrating the capability of the S-IVB stage in support of the Saturn V Apollo program. In addition, the following missions may be performed:

(a) Apollo re-entry.
(b) Voyager - Planetary Orbiter and Lander.

SATURN V

Description: The Saturn first stage (S-1C) will be powered by five Rocketdyne F-1 engines, each of which develops 1.5 million pounds of thrust for a total thrust of 7.5 million pounds. The engines will be arranged in a square pattern of four gimballed engines with one fixed engine in the center of the square pattern. This basic configuration provides for maximum flexibility in that two of the outside engines can be eliminated without redesign, thus providing a more economical stage for missions which do not require the full 7.5 million pounds of thrust. The S-1C will have a propellant capacity of approximately 4.5 million pounds consisting of liquid oxygen and hydrocarbon fuel in two tanks, each approximately 33 feet in diameter. The total length will be approximately 138 feet.

The second stage (S-II) will be powered by five J-2 engines developing 200,000 pounds thrust each, for a total thrust of 1,000,000 pounds. The propellant (liquid oxygen and liquid hydrogen) capacity will be in excess of 900,000 pounds. The second stage will be approximately 33 feet in diameter and approximately 83 feet long. An engine-out capability will be provided.

The third stage (S-IVB) will use one J-2 engine for a total thrust of 200,000 pounds. It will carry 230,000 pounds of liquid oxygen and liquid hydrogen usable propellant loading and will be 260 inches in diameter and 58 feet long.

Mission Capability: The Saturn V Launch Vehicle system will have sufficient payload capability to perform manned lunar-landing missions using a single lunar-orbital rendezvous. Also, provide a basic vehicle for manned circumlunar and lunar orbit missions, and for unmanned lunar and planetary explorations. This launch vehicle will have the capability of putting more than 100 tons in a low earth orbit and of sending more than 40 tons to the vicinity of the moon. Prime emphasis will be placed on the Apollo mission.

NASA sponsors a wide variety of research in space-related science and technology by universities and non-profit organizations. This research ranges from basic investigations to technological applications, and many of the scientific and technological advances recorded in this report were made possible through university efforts. During Fiscal Year 1964, approximately $113.8 million was obligated to university research activity by all NASA sources. Of this amount $36.6 million was obligated by the Sustaining University Program. The balance of the funds supported project-oriented research.

The Sustaining University Program was inaugurated to increase university participation in the nation's expanding space effort, and is designed to: (1) increase the future supply of engineers and scientists trained in space-related fields; (2) assist universities to acquire additional research facilities for conducting space research; and (3) encourage new, creative approaches to research problems and develop new research capabilities.

Under the training element of the program, we continue to aim at an annual yield of about 1,000 Ph.D.'s trained in space-related science and technology. During Fiscal Year 1964, 886 predoctoral graduate students continued their training at 88 universities. One hundred students completed their second year of training and 786 completed their first year. Forty-three additional colleges and universities and 1071 new students were added, bringing the total number of participating institutions up to 131. These institutions now are training a total of 1957 predoctoral students. During the current fiscal year it is planned to increase the number of participating schools to about 142 and add an additional 1250 students. The 131 institutions currently participating are:

*Adelphi University
Alabama, University of
*Alaska, University of
*Alfred University
Arizona State University
Arizona, University of
Arkansas, University of
Auburn University
*Boston College
*Boston University
*Brandeis University
*Brigham Young University
Brooklyn, Polytechnic Institute of
*Brown University
California Institute of Technology
*California, University of (Berkeley)

California, University of (Los Angeles)
*California, University of (Riverside)
*California, University of (San Diego)
Carnegie Institute of Technology
Case Institute of Technology
Catholic University of America
Chicago, University of
Cincinnati, University of
*Clark University
*Clarkson College of Technology
Clemson University
*Colorado School of Mines
Colorado State University
Colorado, University of
Columbia University
Connecticut, University of
Cornell University
*Dartmouth College
Delaware, University of
Denver, University of
Duke University
*Emory University
Florida State University
Florida, University of
*Fordham University
George Washington University
*Georgetown University
Georgia Institute of Technology
*Georgia, University of
*Hawaii, University of
Houston, University of
*Howard University
Illinois Institute of Technology
Illinois, University of
Indiana University
Iowa, State University of
Iowa State University
Johns Hopkins University
Kansas State University
Kansas, University of
Kent State University
*Kentucky, University of
Lehigh University
Louisiana State University
*Maine, University of
Maryland, University of
Massachusetts Institute of Technology
*Miami, University of
Michigan State University

Minnesota, University of
*Mississippi State University
*Mississippi, University of
Missouri, University of
Missouri, University of, at Rolla
*Montana State College
*Montana State University
*Nebraska, University of
Nevada, University of
*New Hampshire, University of
*New Mexico State University
New Mexico, University of
*New York, The City University of
*New York, State University of (Stony Brook)
New York University
North Carolina State College
North Carolina, University of
*North Dakota State University
Northeastern University
Northwestern University
Notre Dame, University of
Ohio State University
*Ohio University
Oklahoma State University
Oklahoma, University of
Oregon State University
Pennsylvania State University
Pennsylvania, University of
Pittsburgh, University of
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island, University of
Rice University
Rochester, University of
*Rutgers, The State University
Saint Louis University
*South Carolina, University of
Southern California, University of
*Southern Methodist University
Stanford University
Stevens Institute of Technology
Syracuse University
Tennessee, University of
Texas A&M University
*Texas Christian University
Texas Technological College
Texas, University of
*Toledo, University of
*Tufts University

Tulane University
Utah State University
Utah, University of
Vanderbilt University
Vermont, University of
Virginia Polytechnic Institute
Virginia, University of
*Washington State University
Washington University (St. Louis)
Washington, University of (Seattle)
*Wayne State University
West Virginia University
Western Reserve University
Wisconsin, University of
Yale University

*Institutions entering the program in Fiscal Year 1964.

The research facilities segment of the Sustaining University Program is concerned with providing adequate laboratory space at universities heavily engaged in scientific and technical activities for the space program. NASA has made a total of twenty-seven facilities grants to date, and the following summary shows pertinent information about each of them:

Institution	Investigator/Topic	Gross Square Feet
Rensselaer Polytechnic Institute	Wiberley/Materials	56,000
Stanford University	Lederberg/Exobiology	15,500
Chicago, University of	Simpson/Space Sciences	42,000
Iowa, State University of	Van Allen/Physics & Astronomy	24,000
California, University of (Berkeley)	Silver/Space Sciences	39,000
Harvard University	Sweet/Biomedicine	4,500
Minnesota, University of	Nier/Physics	15,000
Massachusetts Institute of Technology	Harrington/Space Sciences	75,000
Colorado, University of	Rense/Astrophysics	31,000
California, University of (Los Angeles)	Libby/Space Sciences	67,500
Wisconsin, University of	Hirschfelder/Theoretical Chemistry	13,000
Michigan, University of	Sawyer/Space Sciences	56,000
Pittsburgh, University of	Halliday/Space Sciences	43,000
Princeton University	Layton/Propulsion Sciences	22,000
Lowell Observatory	Hall/Planetary Sciences	8,000

Institution	Investigator/Topic	Gross Square Feet
*Texas A&M University	Wainerdi/Activation Analysis	30,000
*Maryland, University of	Martin/Space Sciences	60,000
*Southern California, University of	Meehan/Human Centrifuge	4,200
*Cornell University	Gold/Space Sciences	38,000
*Rice University	Dessler/Space Sciences	55,000
*Purdue University	Zucrow/Propulsion	1,300
*Washington University (St. Louis)	Norberg/Space Sciences	25,000
*New York University	Ferri/Aeronautics	21,000**
*Georgia Institute of Technology	Picha/Space Sciences	51,000
*Arizona, University of	Kuiper/Space Sciences	50,000
*Brooklyn, Polytechnic Institute of	Bloom/Aerospace	16,000**
	Total	914,000

* Fiscal Year 1964 Program.
**In process.

The research part of the Program affords universities the maximum opportunity to balance and strengthen existing areas of space-related work and stimulate the development of new ideas and talent, particularly in those areas which fall outside the specific responsibility of an individual NASA organizational element, but which are of vital importance to the overall NASA mission. A carefully developed research program, supported on a flexible, long-range basis, provides valuable augmentation of existing work, the opportunity to fill gaps, consolidate existing work, and encourage the development of young researchers and the germination of new ideas. To the university already heavily involved in space-related research, this program provides an opportunity to make more efficient use of its assets. To the school which has not been engaged previously in space research to an appreciable degree, it provides an incentive for the university researcher to remain at his institution where he can create an attractive nucleus of interest for young researchers which offsets the drift of talent to the larger and better known institutions. The effect is to broaden the base of university participation in the space program and increase the overall national research capability. Institutions currently participating in research supported by the Sustaining University Program are:

Adelphi University
Alabama, University of
California, University of (Berkeley)
California, University of (Los Angeles)
California, University of (San Diego)
California Institute of Technology
Columbia University
Denver, University of
Florida, University of

Graduate Research Center of the Southwest
Georgia Institute of Technology
Kansas, University of
Kansas State University
Maine, University of
Maryland, University of
Massachusetts Institute of Technology
Minnesota, University of
Montana State College
New York, City College of
New York University
Oklahoma State University
Pennsylvania, University of
Pittsburgh, University of
Princeton University
Texas A&M University
Virginia, University of
Washington University (St. Louis)
West Virginia University
William and Mary, College of
Wesleyan University
Wisconsin, University of
Yale University
Yeshiva University

During Fiscal Year 1965, the Sustaining University Program budget is $46 million: $25 million has been allocated to training, $10 million has been allocated to research facilities, and $11 million to research. It is anticipated that other program offices and centers will put an additional $80 million into project-oriented research.

COSTS OF LAUNCHED SPACECRAFT (MILLIONS OF DOLLARS)

Orbiting Astronomical Observatories

Spacecraft	(10)*	$ 467.9
Atlas-Agena	(10)	120.0
Total		$ 587.9

Unit cost $58.79 million

Orbiting Geophysical Observatories

Spacecraft	(11)*	$ 317.4
Atlas-Agena	(8)	65.7
Thor-Agena	(3)	18.2
Total		$ 401.3

Unit cost $36.48 million

Orbiting Solar Observatories

Spacecraft	(8)*	$ 72.3
Delta Dev. Veh.	(1)	2.5
Delta Proc. Veh.	(7)	20.4
Total		$ 95.2

Unit cost $11.9 million

Advanced Orbiting Solar Observatories

Spacecraft	(4)*	$ 142.4
TAT Agena	(4)	25.0
Total		$ 167.4

Unit cost $41.8 million

Beacon Explorer

Spacecraft	(3)*	$ 4.2
Scout	(2)	2.4
Delta	(1)	2.9
Total		$ 9.5

Unit cost $3.17 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

Atmospheric Explorers

Spacecraft	(4)*	$	12.1
Delta	(4)		11.7
Total		$	23.8

Unit cost $5.95 million

Ionosphere Explorers

Spacecraft	(2)*	$	3.9
Scout	(2)		2.5
Total		$	6.4

Unit cost $3.2 million

Air Density Explorers

Spacecraft	(7)*	$	3.7
Scout	(7)		8.4
Total		$	12.1

Unit cost $1.7 million

Geodetic Explorers

Spacecraft	(7)* ((5) Active ((2) Passive	$	23.5
Delta	(5)		15.5
Thor Agena	(2)		12.6
Total		$	51.6

Unit cost $7.4 million

Radio Astronomy Explorers

Spacecraft	(5)*	$	18.9
Delta	(5)		14.5
Total		$	33.4

Unit cost $6.68 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

University Explorers 1/

Spacecraft	(11)*	$ 26.3
Scout	(11)	13.2
Total		$ 39.5

Unit cost $3.59 million

International Satellites 1/

Spacecraft	(18)*	$ 27.0
Scouts	(12)	14.9
Delta (Dev.)	(1)	2.5
(Proc.)	(3)	9.3
Thor-Agena	(2)	18.8
Total		$ 72.5

Unit cost $4.03 million

Does not include spacecraft cost funded by International Groups.

Energetic Particles Satellites

Spacecraft	(6)*	$ 14.9
Delta (Dev.)	(2)	5.5
(Proc.)	(4)	12.7
Total		$ 33.1

Unit cost $5.51 million

Probes

IMP

Spacecraft	(11)*	$ 45.6
Delta	(11)	36.8
Total		$ 82.4

Unit cost $7.49 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

1/ Five back-up Scout Vehicles being planned for procurement to support International (ESRO) and University Launches, if required.

LUNAR ORBITER

Spacecraft	(10)*	$ 187.8
Atlas-Agena	(10)	79.8
Total		$ 267.6

Unit cost $26.7 million

VOYAGER

Spacecraft	(4) *	$ 780.0
Saturn 1B	(4)	197.0
Total		$ 977.0

Unit cost $244.25 million

TIROS

Spacecraft	(11)*	$ 54.1
Delta Development	(5)	12.5
Procurement	(5)	15.1
Total		$ 81.7

Unit cost $7.43 million

NIMBUS

Spacecraft	(7) *	$ 299.0
Thor-Agena	(7)	47.2
Total		$ 346.2

Unit cost $49.5 million

ECHO

Spacecraft	(3)*	$ 11.8
Delta	(2) (Development Vehicles)	5.0
Thor-Agena	(1)	8.6
Total		$ 25.4

Unit Cost $8.5 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

Probes

BIOSATELLITES

Spacecraft	(6)*	$ 46.5
Delta	(6)	21.0
Total		$ 67.5

Unit cost $11.25 million

PIONEER

Spacecraft	(11)*	$ 115.8
Delta	(11)	37.1
Total		$ 152.9

Unit cost $13.9 million

RANGER

Spacecraft	(9)*	$ 168.8
Atlas-Agena	(9)	96.1
Total		$ 264.9

Unit cost $29.43 million

SURVEYOR Lander

Spacecraft	(17)*	$ 523.4
Centaur	(17)	228.9
Total		$ 752.3

Unit cost $44.25 million

MARINER-MARS 1964

Spacecraft	(2 *	$ 87.7
Atlas-Agena	(2)	24.9
Total		$ 112.6

Unit cost $56.3 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.

ADVANCED TECHNOLOGICAL SATELLITE

Spacecraft	(5) *	$ 112.9
Atlas-Agena	(5)	39.8
Total		$ 152.7

Unit cost $30.5 million

RELAY

Spacecraft	(2) *	$ 35.7
Delta	(2)	6.0
Total		$ 41.7

Unit cost $20.9 million

SYNCOM

Spacecraft	(3) *	$ 24.1
Delta	(3)	12.4
Total		$ 36.5

Unit cost $12.2 million

*Costs include experiment design and fabrication, spacecraft assembly and test, and data analysis.